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Journal of Maize Research and Development (JMRD) is dedicated to publishing high-quality original research and review articles on maize breeding, genetics, agronomy, entomology, pathology, post harvest, soil science, ecology, botany, physiology, biochemistry, genomics, conservation agriculture and climate change effect on maize, maize economics, extension, statistics, up-scaling research on maize and plant biotechnological approaches for maize improvement. The main objective of JMRD is to serve as a platform for the international scholars, academicians, researchers, and extensonists to share the innovative research findings in maize. The JMRD is an online open access international, peer reviewed and official journal published biannually in month of June and December by National Maize Research Program, Rampur, Chitwan, Nepal. This Journal offers authors no publishing charges, no proofreading charges, no page charges and fast publication times. As soon as the paper is ready, it will be appeared online.

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Editorial preface

Maize is one of the most important food crops world-wide, serving as staple food, livestock feed, and industrial raw material. Among cereal crops, maize has the highest average yield per ha and remains third after wheat and rice in total area and production in the world. There is an enormous possibility to increase the maize yield so various biotic and abiotic yield limiting factors including poor crop management practices should be addressed with innovative research efforts targeted to address those constraints. The developed technologies should be farmer friendly and easily access to concerned stakeholders.

Journal of Maize Research and Development (JMRD) is dedicated to publishing high-quality original research and review articles on maize breeding, genetics, agronomy, entomology, pathology, post harvest, soil science, botany, physiology, conservation agriculture and climate change effect on maize, maize economics, up-scaling research on maize and plant biotechnological approaches for maize improvement. The main objective of JMRD is to serve as a platform for the international scholars, academicians, researchers, and extensonists to share the innovative research findings in maize. The JMRD is an online open access international, peer reviewed and official journal published biannually in month of June and December by National Maize Research Program, Rampur, Chitwan, Nepal. Authors can now submit articles online - register with the journal prior to submitting, or if already registered can simply log in and begin the 5 step process. Reviewers can also register with the journal.We are so happy and excited to publish our third edition with 10 diverse manuscripts with latest findings from maize research and development field devoted to enhancing the maize global cultivation. Our team always focused and gives priority on quality publications with its wider and easy global access. Keeping those things in view, Journal of Maize Research and Development has been listed in so many national and international indexing, abstracting and cataloguing of AGORA-Access to Global Online Research in Agriculture, CAB Abstracts (CABI), DOAJ – Directory of Open Access Journals, Google Scholar, JournalTOCs, J-Gate, NARC Online Library, NepJOL (INASP), ResearchGate, TEEAL- The Essential Electronic Agricultural Library, Publons, Genamics Journal Seek, Cabell's Directory, SCOPUS Elsevier (In the process).This huge number of indexing, abstracting and electronic library catalogue demonstrates that our scientific publishing have been globally recognized.

We would like to express our very great appreciation to all the editors and reviewers who contributed to review/edit articles for this issue and all authors for choosing our journal. This edition is also the outcome of continuous efforts and guidance of many academicians and researchers who forever inspired and pushed us to continue our activities in publication and we would like to take this opportunity to share our deep sense of sincere gratitude and immense love to all those who made our every events successful during the period of collection, review and processing of manuscripts. Last but not the least, in order to access the online version of this issue along with archived editions please visit our website http://nmrp.gov.np/journal-of-maize-research-and-development. We encourage authors to submit their articles and readers to provide constructive comments and feedback about the journal.

Jiban Shrestha
Editor-In-Chief
25th December, 2017

Subash Subedi, Ph.D.
Associate Editor-In-Chief
25th December, 2017

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Comparative study of impact of *Azotobacter* and *Trichoderma* with other fertilizers on maize growth

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ABSTRACT

Biofertilizers may be a better eco-friendly option to maintain soil fertility. The study was conducted to investigate the effect of *Azotobacter* and *Trichoderma* on the vegetative growth of maize (*Zea mays* L.) plants. The experiment was carried out in medium sized pots, at IAAS, Lamjung (Feb 2017 - May 2017) in completely randomized design (CRD), consisting eight treatments and three replications. Treatments were namely T1 (control), T2 (*Azotobacter*), T3 (*Trichoderma*), T4 (*Azotobacter* + *Trichoderma*), T5 (NPK), T6 (*Azotobacter* + *Trichoderma* + FYM), T7 (*Azotobacter* + *Trichoderma* + FYM + NPK), T8 (FYM). *Azotobacter* showed a positive increase in plant height, stem girth, dry shoot weight, root length and width, and root weight while *Trichoderma* displayed either negative or minimal impact. Effect of FYM was lower than *Azotobacter* but considerably higher than *Trichoderma*. *Trichoderma* seriously inhibited the expression of *Azotobacter* when used together. *Trichoderma* even suppressed the outcome (except shoot weight) of FYM when used together. Root length was the longest in *Azotobacter* inoculation. The highest number of leaves was in T7 followed by *Azotobacter* (T2) and NPK (T5). Unlike leaf width, *Azotobacter* showed a negligible increase in leaves length while *Trichoderma* wherever present showed the negative impact. Minimum chlorophyll content was found in *Azotobacter* or *Trichoderma* after 73 days. *Azotobacter* treatment showed early tasseling than *Trichoderma*. The association of *Azotobacter* and *Trichoderma* increased the biomass. *Azotobacter* has significant effects on growth parameters of maize and can supplement chemical fertilizer, while *Trichoderma* was found to inhibit most of the growth parameters.

Keywords: *Azotobacter*, *Trichoderma*, Maize, Farmyard manure, NPK

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INTRODUCTION

Maize (*Zea mays*) is second most important crop after rice in terms of area and production in Nepal. In the context of Nepal, the importance of maize increase with altitude, eventually standing as a staple crop in northern part of the country (KC et al., 2015). In the context of world, 58% of maize is utilized in animal feed, 16% in human food and 26% in bioethanol production (HLPE, 2013), whereas, study shows that 60%, 25% and 3% of grain were used for animal feed, food and seed respectively in the hilly district of Nepal and rest is sold to the traders (Timsina et al., 2016). Mainly, organic manure (FYM), urea, green manure and recently some kinds of biofertilizer are being used as the source of nitrogen in Nepal. Application of nitrogen and phosphate biofertilizers in maize results in significant increase in plant height, root and shoot weight, ear weight, number of grain per cob, and grain yield (Beyranvand et al., 2013). Addition of both nitrogen and phosphorus fertilizers is necessary to attain the maximum yield (Farnia & Ashjardi, 2015).

Azotobacter, an aerobic free-living soil microbe widely used as biofertilizer, binds atmospheric nitrogen and release it in the form of ammonium ions into the soils. They are ubiquitous and abundantly found in neutral to weakly acidic soils. In dry soils, *Azotobacter* can survive in the form of cysts for up to 24 years (Moreno et al., 1986). Nitrogen application base on soil test and in inoculation of soil with 2 kg/ha bacteria produced the highest number of grains per row, the total number of grains per corn, the weight to 1000-grain, harvest index is produced that make increase of seed/grain yield (Amiri & Rafiee, 2013). Nitragin (*Azotobacter*, *Azospirillum*, *Pseudomonas*) inoculation seeds have 44% higher LAI and 61% higher leaf chlorophyll index and 24% increase in ear dry weight (Kouchebagh et al., 2012).Regardless of organic matter application, inoculation of corn with *Azotobacter* resulted in an increase of 78.7% in dry matter yield when compared with application of urea only (Soliman & Abel Momen, 1994). *Azotobacter* enhanced biofertilizer has the significant increase in plant growth and yield of maize (Wani et al., 2016). Highest yield may be due to maximum leaf area, highest weight of leaf and highest chlorophyll content. Also, highest biomass and greatest harvest index were recorded over other treatments.Inoculation of seeds with *Azotobacter* and *Azospirillum* produced more yield compared to fertilizer application alone (Laxminarayana, 2001).

Trichoderma refers to the genus of fungi, which mostly have a mutualistic relationship with plants. It consists of many species, about 100 identified by molecular data till now (Druzhinina, Kopchinskiy, & Kubicek, 2006). These are typically fast growing at 25°-30°C but can grow well up to 45°C. Several strains of *Trichoderma* have been used as biocontrol agent due to several mechanisms like antibiosis, parasitism, host-plant resistance and competition which has now been popular as biofertilizer and biopesticide together (Kaewchai et al., 2009). *Trichoderma* enriched biofertilizers are being used due to their recognized roles in growth, yield and nutritional quality of various crops including- maize, bean, cucumber, and tomato (Yedidia et al., 1999; Hoyos-Carvajal et al., 2009; Molla et al., 2012; Saravanakumar et al., 2017). *Trichoderma*, being a fungus, affects positively or negatively to higher plants. Kleifeld & Chet (1992) and Harman et al (2004) reported stimulating effects of *Trichoderma* on maize growth whereas there are many others reporting negative growth as well (Kohl & Schlösser, 1989). Pathogenic isolates of *Trichoderma* spp on maize were reported by McFadden and Sutton (1975).

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The application of *T. harzianum* on maize increases all measured parameters which include growth parameters, chlorophyll content, starch content, nucleic acids content, total protein content and phytohormones content of maize plants, when applied to the soil or the seeds but the magnitude of the increase was much more pronounced in case of plants developed from seeds treated with various concentrations of metabolic solution of *T. harzianum* (Akladious & Abbas, 2012). Iranian *Trichoderma* on seed germination show reduced the speed of seed germination on maize (Hajieghrari, 2010). However, only limited information is available on effects of antagonistic fungi on higher plants. The exact physiology of *Trichoderma* as a biofertilizer is yet to be studied.

MATERIALS AND METHODS

Experimental Site

The research was carried out in the location of Sundarbazzar, Lamjung, western hills of Nepal during the spring season (February 2017 – June 2017). The site is located at an elevation of 610 masl with the latitude of 28° 8' 41''N and longitude of 84° 24' 43'' E.

Soil Analysis

The pH, organic matter, nitrogen, phosphorus, and potash content of the soil sample were analyzed.

Design of Experiment

The experiment was carried out in the pot with eight treatments and three replications following Completely Randomized Design (CRD). There were 24 pots in total, each having single maize plant. To maintain suitable moisture condition in the pot, the hole was drilled into the pot. For pot filling, the soil was collected from the horticultural farm of IAAS, Sundarbazaar, Lamjung Nepal. Nearly 2.5 kg of thoroughly mixed soil was filled into the pot (15 cm in diameter and 15 cm in height). Two maize seeds of Arun-2 variety were, then, placed in each pot for germination insurance. Maize seeds were collected from a commercial seed trader of Sundarbazaar, Lamjung, Nepal. Seed inoculation for *Azotobacter* and soil inoculation technique for *Trichoderma viride* was used.

The treatments were control (T1), *Azotobacter* seed coated (T2), *Trichoderma* soil inoculated (T3), *Azotobacter* seed coated + *Trichoderma*soil inoculated (T4), only inorganic fertilizer 120:40:40 NPK kg ha^{-1} (T5), *Azotobacter* seed coated + *Trichoderma* soil inoculated + 10 t FYM ha^{-1} (T6), *Azotobacter* seed coated + *Trichoderma* soil inoculated + 10 t FYM ha^{-1} +120:40:40 NPK kg ha^{-1} (T7) and only FYM (T8). For control, neither manure and nor fertilizer was applied. Fertilizer sources were *Azotobacter*, *Trichoderma*, FYM and chemical fertilizer (Urea for Nitrogen). FYM was used from the IAAS Campus Farm at the rate of 10 ton/ha.

The amount of fertilizer, biofertilizer, and FYM for one plant was calculated using a formula for the estimation of plant population per hectare (Pp). The total amount of fertilizer, biofertilizer, and FYM required for one hectare was divided by plant population per hectare. Thus, the need for amount per plant was obtained.

$$Pp = \frac{10{,}000\ m^2\ X\ number\ of\ seeds\ per\ stand}{Product\ spacing\ (m^2)} \text{------------- ---------------------------- Eq. (1)}$$

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The product of spacing used was 75cm × 25cm while the number of seed per stand was 1. This resulted in plant population of 53,333 plants per hectare (Olaniyan et al., 2004; Okoroafor et al., 2013).

$$Fertilizer\ per\ plant = \frac{Amount\ of\ fertilizer\ per\ hectare}{Plant\ population\ per\ hectare}$$ ------------------------ Eq. (2)

187.5 gm of well-decomposed FYM (Farmyard manure) per pot was used as each plant. As inorganic fertilizer 120 kg of urea, 40 kg of MOP and 40 kg of DAP were used for nitrogen, phosphorous and potassium (NPK) source for a hectare.

Maize being a heavy feeder crop requires a huge amount of nutrients in comparison to other cereals. A normal dose of 120:40:40 kg NPK/ha for the nutrient supplement of the crop (Urea-4.25 g, MOP-1.25 g, DAP-1.63 g per pot) was applied. Half urea was applied as basal dose and the half was top dressed.

Trichoderma soil inoculation

Azotobacter spp. was seed inoculated, in the dose guided by the label, 40 g for 0.25 ha. Per plant share was calculated and applied. Seed inoculation with *Azotobacter* was carried out by 10% sugar solution carrier. To inoculate *Trichoderma viride*, 0.02 % solution was prepared and 150 ml of *Trichoderma* solution was used per pot, directly to the soil.

Sowing, Irrigation, and Top Dressing

Sowing and light irrigation were done on February 23, 2017. After the complete germination, the maize plants were thinned out leaving single maize plant in each pot. Irrigation with 250 ml of water was done whenever necessary. Due to the small capacity of pots and very high temperature during critical stages, irrigating the pots daily was required in case of no rainfall day. The top dressing was essential due to the small size of pot and deficiency symptoms. It was done on 26 days after sowing. Dibbling was used as top dressing method.

Weed control and Harvesting

Hand weeding was done, whenever necessary. Minor aphid infestation was controlled by spraying detergent water (0.005%) to maize plants for two weeks on alternate days. Harvesting was done manually on June 20, 2017 (113 days after sowing).

Data Collection

Days of germination, plant height, stem girth, leaf number, leaf length and width, SPAD reading, days to tasseling, root length and width, dry root and shoot weight, and total biomass were taken.

Data Analysis

MS-Excel version 13 was used to record the data and perform simple statistical analysis as well as table, charts, and graph. Further statistical analysis to determine the significance (at a level of 5%) among various treatments was performed using Genstat version 15.

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RESULTS AND DISCUSSION

The soil pH was found to be acidic 6.0, organic matter 2.81% (medium), nitrogen 0.14% (medium), phosphorus 216.68 kg/ha (high) and potash 534.9 kg/ha (high). *Trichoderma* showed delayed germination (7.3 days) compared to *Azotobacter* (7 days) or control (7 days). *Trichoderma* when used with *Azotobacter* inhibited the response of *Azotobacter* and delayed the germination (7.3 days). NPK (T5), *Azotobacter* + *Trichoderma* + FYM (T6) and FYM (T8) showed faster germination (6.67 days). The fastest germination was observed in T7 (*Azotobacter* + *Trichoderma* + FYM + NPK) of 6.5 days. Though the speed of germination was different, but the rate of germination was same for all the treatments. Inhibition or delayed germination with *Trichoderma* is supported by Hajieghrari (2010), while *Azotobacter* expedites the germination as shown by Bákonyi et al (2013).

Out of all the eight treatment for maize plant, T7 (*Azotobacter*, *Trichoderma*, FYM and NPK) had the highest value for the parameters like plant height, dry shoot weight, stem girth, dry root weight, and root width with an increase of 37.7%, 269.5%, 58.2%, 793.8%, and 67.8% respectively over control T1 (soil only). T7 was followed by T5 (NPK only) and T2 (*Azotobacter* only) successively in all above parameters like plant height, dry shoot weight, stem girth, dry root weight, and root width with an increase of 31.8%, 244.6%, 50%, 296.4%, 42.8% and 23.48%, 59.5%, 10%, 149.5%, 27.4%.T8 (FYM only) followed T2 in terms of parameters like plant height, stem girth, dry root weight, and root width 18.8%, 9.3%, 41.0%, 10.4% respectively. *Trichoderma* (T3) showed a negative impact on the plant height and stem girth with a decrease of 8.6% and 3.2% over control. *Trichoderma* showed the negligible increase of 4.9%, 8.8% and 2.2% in dry shoot weight, root weight, and root width respectively.

Table 1: Effects of different treatments on different parameters of maize in Lamjung

Treatment	Plant height (cm)	Stem girth (cm)	Root length (cm)	Root Width (cm)	Dry root weight (g)
T1	$126.2^{b}\pm1.42$	$2.803^{a}\pm0.04$	$39.4^{c}\pm0.52$	$4.53^{a}\pm0.15$	$10.73^{a}\pm0.7$
T2	$155.8^{e}\pm3.97$	$3.078^{a}\pm0.12$	$44.1^{cd}\pm1.01$	$5.77^{b}\pm0.26$	$26.77^{b}\pm1.94$
T3	$115.3^{a}\pm1.2$	$2.711^{a}\pm0.09$	$44.7^{e}\pm0.67$	$4.63^{a}\pm0.22$	$11.67^{a}\pm0.92$
T4	$146.9^{cd}\pm1.31$	$2.864^{a}\pm0.15$	$41.4^{cd}\pm0.67$	$4.83^{a}\pm0.22$	$13.87^{a}\pm0.81$
T5	166.3f±0.64	$4.2^{b}\pm0.16$	$31.3^{a}\pm0.6$	$6.47^{c}\pm0.26$	$42.53^{c}\pm4.88$
T6	$143^{c}\pm2.08$	$3.022^{a}\pm0.03$	$43.1^{de}\pm0.73$	$4.73^{a}\pm0.26$	$15.13^{a}\pm1.67$
T7	$170^{f}\pm1.0$	$4.43^{b}\pm0.47$	$35^{b}\pm1.0$	$7.9^{d}\pm0.1$	$95.9^{d}\pm14.9$
T8	$149.9^{d}\pm0.93$	$3.055^{a}\pm0.27$	$40.33^{c}\pm0.88$	$5^{a}\pm0.1$	$15.43^{ab}\pm2.0$
Grand Mean	145.66	3.22	39.76	5.378	26.096
S.E.	3.28	0.298	1.294	0.358	6.64
LSD	5.877**	0.534**	2.318**	0.64**	11.9**
CV%	2.3%	9.3%	3.3%	6.7%	25.5%
p value	<0.001	<0.001	<0.001	<0.001	<0.001

T1 = Control; T2 = *Azotobacter*; T3 = *Trichoderma*; T4 = *Azotobacter* + *Trichoderma*; T5 = NPK; T6 = *Azotobacter* + *Trichoderma* + FYM; T7 = *Azotobacter* + *Trichoderma* + FYM + NPK; T8 = FYM; ** means Highly significant.

Trichoderma with *Azotobacter* in T4 or with *Azotobacter* and FYM (T6) highly suppressed the performance of *Azotobacter* and/or FYM. The increase of plant height, dry shoot weight and

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stem girth in T4 and T6 were 16.4%, 43.6%, 2.1% and 13.3%, 42.6%, 7.9% respectively. With FYM, the increase of shoot weight was 23.1% only.

Table 2: Effects of different treatments on different parameters of maize in Lamjung

Treatment	Leaf number on 85 DAS	Leaf length (cm)	Leaf width (cm)	Dry shoot weight (g)	Dry biomass (t ha^{-1})
T1	$11.67^{a}\pm0.33$	$39.9^{a}\pm1.69$	$5.2^{ab}\pm0.1$	$31.3^{a}\pm1.56$	$0.934^{a}\pm0.05$
T2	$16.67^{de}\pm0.33$	$56.33^{c}\pm0.67$	$4.8^{a}\pm0.36$	$43.93^{a}\pm3.64$	$1.571^{b}\pm0.11$
T3	$14^{bc}\pm1.0$	$47.37^{b}\pm1.48$	$5.17^{ab}\pm0.34$	$32.83^{a}\pm1.72$	$0.989^{a}\pm0.06$
T4	$13.33^{ab}\pm0.88$	$62.17^{d}\pm1.48$	$5.33^{ab}\pm0.48$	$44.93^{a}\pm1.99$	$1.307^{ab}\pm0.06$
T5	$15.67^{cd}\pm0.33$	$59.97^{cd}\pm1.5$	$7.43^{c}\pm0.88$	$107.87^{b}\pm12.54$	$3.342^{c}\pm0.39$
T6	$15.67^{cd}\pm0.88$	$47.53^{b}\pm1.3$	$4.83^{a}\pm0.03$	$44.63^{a}\pm3.74$	$1.328^{ab}\pm0.11$
T7	$18^{e}\pm1.0$	$79.3^{e}\pm1.7$	$6.4^{bc}\pm0.5$	$115.65^{b}\pm4.85$	$4.701^{d}\pm0.44$
T8	$13^{ab}\pm0.58$	$62.17^{d}\pm1.3$	$5.6^{ab}\pm0.15$	$38.53^{a}\pm3.72$	$1.199^{ab}\pm0.12$
Grand Mean	14.609	55.865	5.561	54.93	1.801
S.E.	1.193	2.388	0.741	9.28	0.324
LSD	2.137**	4.279**	1.328**	16.63**	2.393**
CV%	8.2%	4.3%	13.3%	16.9%	18%
p value	<0.001	<0.001	<0.001	<0.001	<0.001

T1 = Control; T2 = *Azotobacter*; T3 = *Trichoderma*; T4 = *Azotobacter* + *Trichoderma*; T5 = NPK; T6 = *Azotobacter* + *Trichoderma* + FYM; T7 = *Azotobacter* + *Trichoderma* + FYM + NPK; T8 = FYM; ** Highly significant.

The rapid increase in height in T7 and T5 is due to the top dressing of N. N fertilizer causes increases in plant height in results found by Chandler (1969); Eltelib et al (2006) and Amin (2011) which is associated with the fact that N promotes plant growth, thus increases the number of internodes, and length of internodes consequently increasing plant height. El-Hoseiny and Rabie (1979) found that bacterization of maize with *Azotobacter* inclined to stimulate the growth of treated plants as characterized by the increase of root and shoot lengths. It is also observed that plant height and internode length of the corn stalks increased by the use of bacterium *Azotobacter* which produce cytokinin and its precursors (Nieto & Frankenberger, 1991). Mirza et al (2000) reported that application of biofertilizers apart from nitrogen fixation, cause the production of auxin that increases lethal fibers and the absorption of nutrients, and consequently improves plant height.

The effects of biological control agent (based on antibiosis, fungistatic and mycoparasitism) *Trichoderma* is of particular relevance because of the possibility that these antagonists of fungi could also negatively interfere with AMF too. Effects of *Trichoderma* are difficult to generalize, because of the aggressiveness of the *Trichoderma* strain used and their survival. Negative efficacy of *Trichoderma* secondary metabolites is in agreement with Menzies (1993) in cucumber, tomato, and pepper. Hajieghrari (2010) reported the pathogenesis of *Trichoderma* rather than symbiosis causing necrosis and poor performance. It is reported that the damage of *Trichoderma* species are species-specific or depend on *Trichoderma*-maize interaction. *Trichoderma* with *Azotobacter* or with *Azotobacter* and FYM highly suppressed the performance of *Azotobacter* and/or FYM which might be particularly due to competition among the microorganisms in the rhizosphere or for the reasons unknown.

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Addition of nitrogen increases stem girth (John & Warren, 1967). Pronounced effect on stem girth of maize by *Azotobacter* application may be due to enough N fixations. A similar result on stem diameter was reported by Mirza et al. (2000). *Trichoderma* has inhibiting effects on stem girth, which may be due to an interference of this fungicide to AMF or competitiveness with rhizospheric microorganisms or with available key-nutrients, or out-competing *Azotobacter*. Although *Trichoderma* has rarely been regarded as a parasite, there are several reports demonstrating pathogenicity of *Trichoderma* to maize seed and seedlings (Mc-Fadden and Sutton, 1975; Sutton, 1972), as well as other seeds (Menzies, 1993; Hermosa et al., 2012).

Inorganic fertilizer NPK showed a decrease of 20.5% and 12.7% in root length of T5 and T7 respectively over control. The longest root length was seen in *Azotobacter* (T2) of 12.0% increase. *Trichoderma* (T3) displayed an increase of 5.7% which was 5.0% when *Azotobacter* and *Trichoderma* came together (T4), the antagonistic effect was observed. With FYM (T8), only 2.3% of the increase was observed which rapidly rose to 9.5% when FYM combined with *Azotobacter* and *Trichoderma* (T6).

Inoculation with biofertilizers causes an increase in root weight. This significant increase in root values may be related to increases in the availability of minerals especially N due to N fixation that may lead to an increase photosynthesizing surface. Thus, increase in accumulation of simple sugars and starch in roots occurred and resulted in enhancement of roots. This result is in line with those obtained by El-Gamal (1996) on potato tubers and Sheikh et al (2000) on Duch iris. The decrease in the root-shoot ratio of maize due to *Trichoderma* inoculation is demonstrated by Hajieghrari (2010).

The highest number of leaves in the maize plant was in treatment T7 (a combination of all sorts of fertilizer) with an increase of 54.2% respectively over control. Interestingly NPK (T5) treatment showed less number of leaves than *Azotobacter* (T2) (34.3% vs 42.8%). *Trichoderma* (T3) showed 20.0% of the increase in leaves while FYM (T8) had only 11.4% of the increase. Together *Azotobacter* and *Trichoderma* (T4) had 14.2% of the increase in leaves which increased to 34.3% when also combined with FYM (T6). The highest leaf length was found in T7 (52.8%) followed by T5 (30.3%). T8 and T2 showed the negligible increase of 1.3% and 0.16% over control while *Trichoderma* wherever present showed the negative impact. *Trichoderma* (T3) decreased the leaf length by 5.3% over control (T1) and T6 by 3.0%, while no change was observed in T4. On the contrary to leaf length, leaf width was highest of all in T5 (NPK only) with an increase of 97.5% followed by T7 (73.4%). There was a decline in width in case of *Azotobacter* (T2) of 2.2% over control, while an increase of 14.1% was observed in *Trichoderma* treatment (T3). The combination of *Azotobacter* and *Trichoderma* in T4 showed a sharp decline of 13.4% over control, but the leaf width increased highly (36.5%) when FYM (T6) was added to it. The increase observed in FYM (T8) was 3.6% only.

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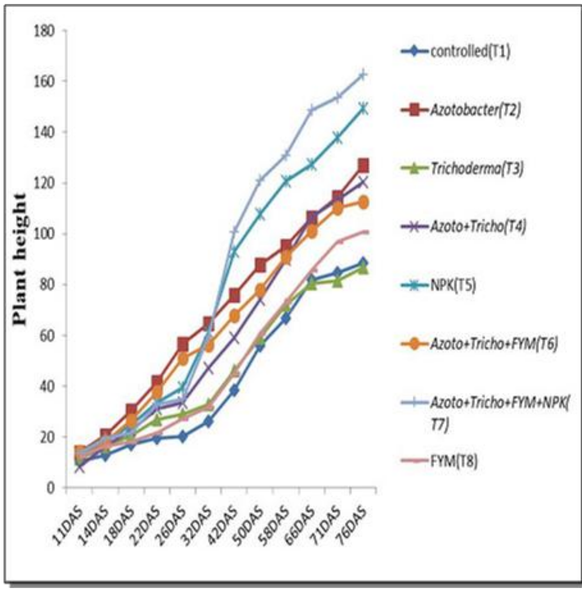

Figure 1: Height of maize plant for a duration

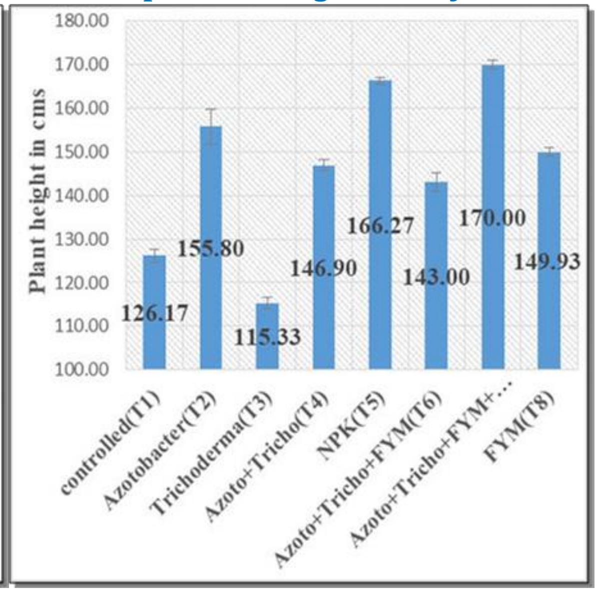

Figure 2: Final height of maize plant

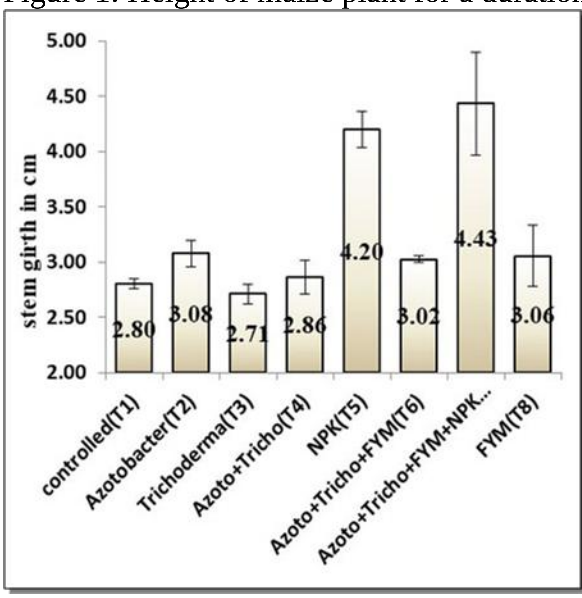

Figure 3: Stem girth of maize plant

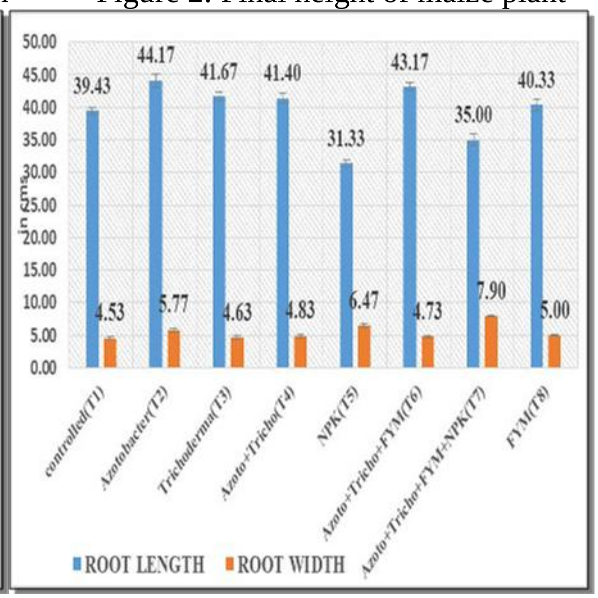

Figure 4: Root length & width of maize plant

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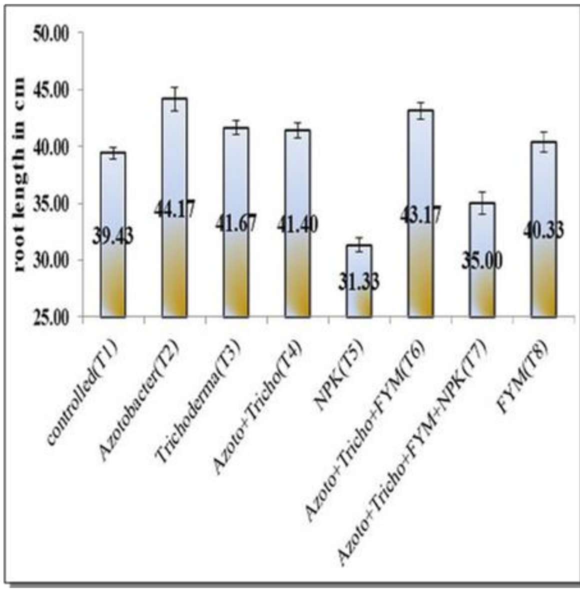


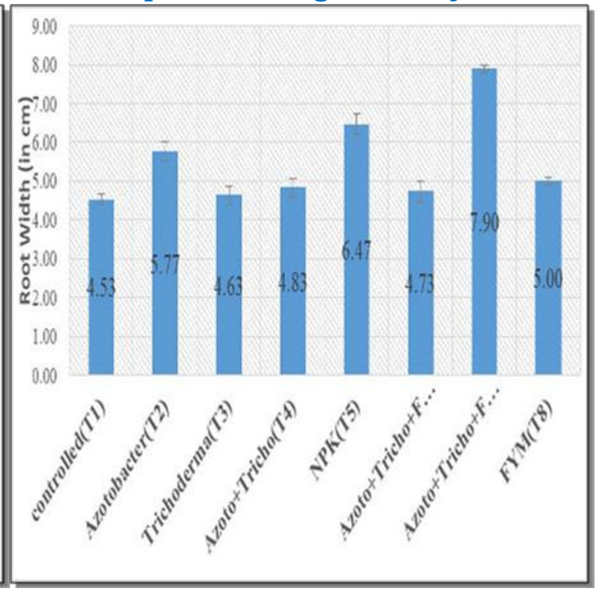
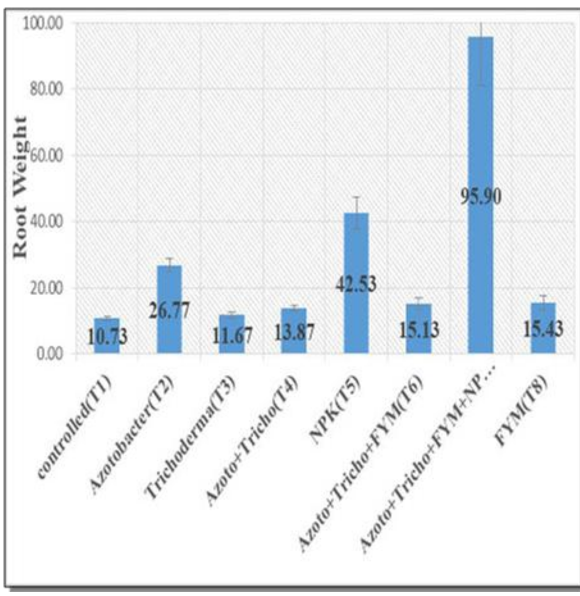


Figure 5: Root length of maize plant

Figure 6: Root width of maize plant



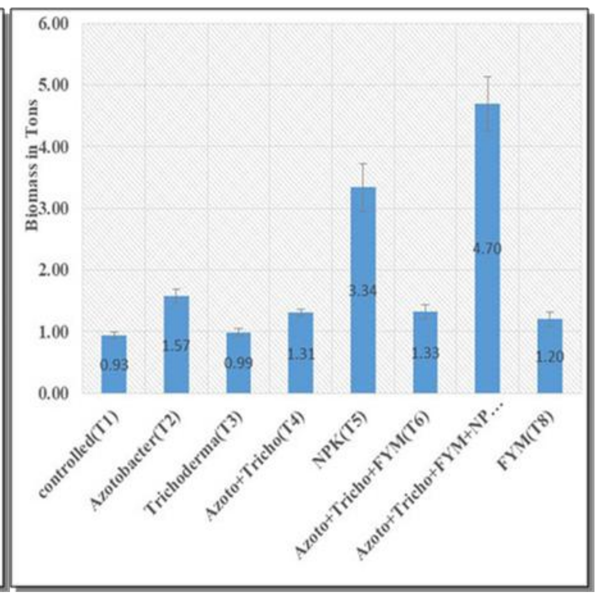


Figure 7: Oven dry root weight of maize after harvesting (in g)

Figure 8: Total biomass of maize (in ton)

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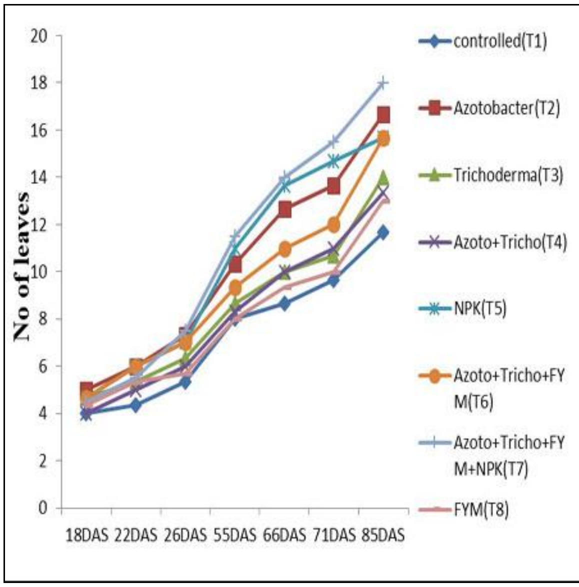

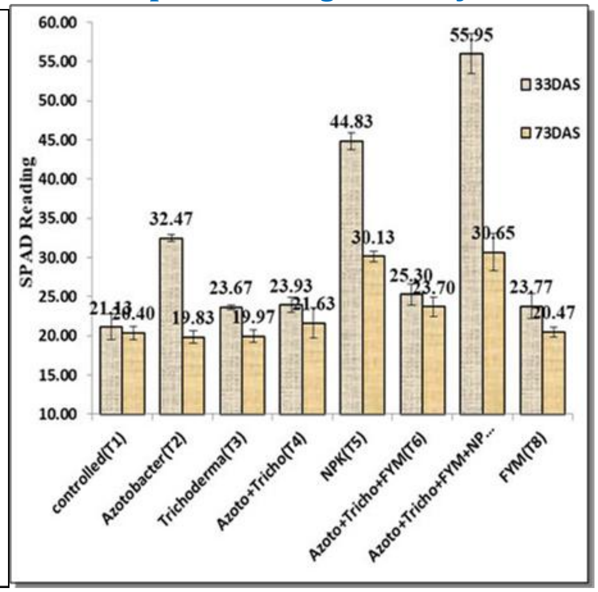

Figure 9: Increment in number of leaves over a duration of maize plant

Figure 10: SPAD reading of maize plant on 33 and 73 days after sowing (DAS)

The enhancement in leaves growth as a result of biofertilizers inoculation may be due to the production of phytohormones by the biofertilizers and/or improving the availability of nutrients (Martin et al., 1989; Jagnow et al., 1991).

Table 3: Effects of different treatments on different parameters of maize in Lamjung

Treatment	Date of germination	Date of tasseling	SPAD reading 33DAS	SPAD reading 73DAS
T1	7±0.0	77^{d}±1	21.13^{a}±1.64	20.4^{ab}±0.84
T2	7±0.58	73.33^{bc}±0.88	32.47^{c}±0.46	19.83^{a}±0.78
T3	7.33±0.33	75^{cd}±1.15	23.67^{ab}±0.27	19.97^{a}±0.75
T4	7.33±0.33	75^{cd}±0.58	23.93^{ab}±0.96	21.63^{ab}±1.92
T5	6.67±0.33	62.67^{a}±1.76	44.83^{d}±1.11	30.13^{c}±0.67
T6	6.67±0.67	74^{bcd}±0.58	25.3^{b}±1.38	23.7^{b}±1.23
T7	6.5±0.5	71^{b}±0.0	55.95^{e}±2.55	30.65^{c}±2.35
T8	6.67±0.33	83.33^{e}±0.88	23.77^{ab}±1.59	20.47^{ab}±0.6
Grand Mean	6.913	74.043	30.313	23.03
S.E.	0.723	1.751	2.167	1.974
LSD	1.295	3.138**	3.883**	3.537**
CV%	10.5%	2.4%	7.1%	8.6%
p value	NS	<0.001	<0.001	<0.001

T1 = Control; T2 = *Azotobacter*; T3 = *Trichoderma*; T4 = *Azotobacter* + *Trichoderma*; T5 = NPK; T6 = *Azotobacter* + *Trichoderma* + FYM; T7 = *Azotobacter* + *Trichoderma* + FYM + NPK; T8 = FYM; ** means Highly significant. NS = Non-significant

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Number of leaves seen in T7 and T5 might be due to more availability of nitrogen which is consistent with Okajina et al. (1983); Woldesenbet and Haileyesus (2016). *Azotobacter* application shows the significant increase in the number of leaves which is in conformity with Barakat and Gabar (1998) in tomato.

Two readings of SPAD were taken on 33 DAS and 73 DAS. In the first reading, T7 showed the highest chlorophyll content increase of 164.8% over control (T1), which was followed by T5 (112.2%), and T2 (53.7%). *Trichoderma* (T3), farmyard manure (T8) and *Trichoderma* with *Azotobacter* (T4) showed a mere increase of 12-13% chlorophyll content. Chlorophyll content rapidly declined towards maturity, being the highest in T7 again, which was statistically at par with T5, followed by T6. Minimum chlorophyll content was found in T2 and T3 after 73 days. This chlorophyll content is too low for proper growth and development of maize. Highest reading of T7 and T5 on 33 DAS was due to the top dressing of urea. Moving on towards maturity, N deficiency symptoms were visible, which caused the rapid decline in SPAD reading of maize.

It is well known that nitrogen is present in chlorophyll molecule. Increase in leaf chlorophyll index was recorded by increasing nitrogen rates also mentioned by Kouchebagh et al. (2012). The obtained results for leaf chlorophyll content may be attributed to the micro-organisms effect on nutrients release in soil in available forms leading to the increase of nitrogen content in the plants; this, in turn, led to increasing the chlorophyll content as reported by Moursi et al. (1998) and Larimi et al (2014). Increase in chlorophyll content was observed in maize inoculated with *Azotobacter* strains which is similar to the findings of Shaukat et al. (2006) in sunflower, El-Gamal (1996) in potato plants and Alexandru et al. (2013). Nitrogen-fixing *Azotobacter* supplies the high amount of nitrogen for tissue growth, thus, increases chlorophyll content (Shanthi et al., 2012).

Days to tasseling was minimum in NPK treatment (T5). The increasing order of tasseling days and treatments were T5 (62.7 days) < T7 (71 days) < T2 (73.3 days) < T6 (74 days) < T3 (75 days) = T4 (75 days) < T1 (77 days) < T8 (83.3 days). The only positive impact of the association of *Azotobacter* and *Trichoderma* was observed in biomass with an increase of 149.8% over control (T1) while *Azotobacter* (T2) had a biomass increase of 68.2% and *Trichoderma* (T3) had an increase of 5.9%. The highest of biomass increase of 403.3% was observed in T7 (*Azotobacter* + *Trichoderma* + FYM + NPK) followed by 257.8% in T5 (NPK only). The increase of biomass in T8 (FYM only) was 28.4% while in T6 (*Azotobacter* + *Trichoderma* + FYM), it was found to be 42.2%. Although application of urea to maize has increased its dry matter significantly, *Azotobacte*r has also significant effects on corn dry matter yield. High dry matter in those treatments is due to long plant height, high stem girth, and high root weights. Fresh biomass yield is higher in high N supplement which is in harmony with Amin (2011). Nitrogen fertilization results in increased maize biomass up to 25-42% in results found by Ogola et al (2002).

Trichoderma shows delayed germination compared to *Azotobacter*. *Trichoderma* when used with *Azotobacter* inhibit the response of *Azotobacter* and delays the germination. Whether inorganic fertilizers NPK or FYM combined *Azotobacter* & *Trichoderma* or FYM itself show faster germination. The fastest germination is observed when biofertilizer, FYM, and inorganic fertilizer are mixed. As far as parameters like plant height, stem girth, dry shoot weight, root

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length and width, and root weight are concerned *Azotobacter* shows a positive increase in all these parameters while *Trichoderma* displays either negative or minimal impact comparative to *Azotobacter*. Impact of farmyard manure is lower than *Azotobacter* but appreciably higher than *Trichoderma*. *Trichoderma* greatly inhibits the expression of *Azotobacter* when used together. *Trichoderma* even suppresses the outcome (except shoot weight) of farmyard manure when used in a combination of *Azotobacter*, *Trichoderma*, and FYM. Though all these parameters are the highest (except root length) in NPK when combined with *Azotobacter*, *Trichoderma*, and FYM, the result is comparable with NPK when used alone. *Azotobacter* or *Trichoderma* or FYM increases root length and number of leaves. *Trichoderma* wherever present showed the negative impact on leaf length, unlike *Azotobacter*. Minimum chlorophyll content is seen in biofertilizer treatment towards maturity. Days to tasseling is comparatively lower for *Azotobacter* than *Trichoderma* while it is minimum in NPK treatment. The only positive impact of the association of *Azotobacter* and *Trichoderma* is observed in biomass increase. While *Trichoderma* merely increases the biomass, *Azotobacter* highly increases total biomass. The highest of biomass increase was in the combination of *Azotobacter*, *Trichoderma*, FYM, and NPK. Although the application of urea to maize increased its dry matter significantly, *Azotobacte*r had also significant effects on corn dry matter yield. High dry matter in those treatments is due to long plant height, high stem girth, and high root weights.

CONCLUSION

Azotobacter spp. showed the positive impact on growth parameters while *Trichoderma viride* inhibits the growth parameters. When combined together, inhibitory nature of *Trichoderma* overlaps or antagonizes the effect of *Azotobacter* in maize plant. So the study indicates that use of *Trichoderma* with seeds may not be a wise choice from growth point of view.

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AUTHOR CONTRIBUTIONS

S.M. conceived and designed the experiments, analyzed the data and wrote the paper, and revised the article for the final approval of the version to be published. S.N. collected the data, analyzed the data and wrote the paper.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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Socio-economic assessment on maize production and adoption of open pollinated improved varieties in Dang, Nepal

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ABSTRACT

Research was conducted from February to May, 2017 for socioeconomic assessment on maize production and adoption of open pollinated improved maize varieties in Dang district of Nepal. Altogether, 100 samples were taken by simple random sampling from the major maize growing areas and relevant publications were reviewed. Focal Group Discussion and Key Informant Survey were also done. Descriptive statistics, unpaired t-test, probit regression and indexing were used for data analysis using statistical tools- SPSS, STATA and MS-Excel. Probit econometric model revealed that ethnicity (1% level), gender (5% level), area under open pollinated improved maize (1% level), seed source dummy (1 % level) and number of visits by farmers to agrovet (5% level) significantly determined the adoption of open pollinated improved maize varieties. In addition, unpaired t-test revealed that the productivity of open pollinated improved maize varieties was significantly higher (at 1% level) than local; also, the multinational companies' hybrids showed significantly higher productivity (at 1% level) when compared to open pollinated improved varieties. Furthermore, indexing identified- lack of availability of quality seeds and fertilizers (I= 0.86) as the major problem associated with the maize production. Giving aggressive subsidy on open pollinated improved seeds and dealership to registered agrovets for selling the subsidy seeds could enhance the adoption. Moreover, government organizations working in the areas of agricultural extension and research must focus on adoption of open pollinated improved maize varieties among the farmers, substituting the local and developing the high yielding hybrid varieties in Nepal to increase the maize productivity.

Keywords: Adoption, maize productivity, probit regression, socioeconomic assessment

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INTRODUCTION

In Nepal, agriculture and forestry sector contributed 31.13 % share to the national Gross Domestic Product (GDP). Maize (891583 ha) is the second most important crop in Nepalese agriculture after rice (1362908 ha) in terms of area. The total maize production and yield of maize have been reported 2231517 t and 2.50 t/ha in Nepal; 53043 t. and 2.3 t/ha in Dang respectively (MOAD, 2017). It would be a wise decision to adopt open pollinated (OP) improved varieties as it yields higher compared to local; also, unlike hybrids, the seeds of open pollinated varieties could be kept for next year. More than 20 open pollinated improved varieties of maize including Poshilo Makai-1 (recommended in 2008 for mid-hills below 1600 m) and few hybrids: Gaurav (recommended in 2003), Rampur hybrid 4 (recommended in 2016) have been developed by National Maize Research Program (NMRP), Chitwan, Nepal.

The total area, production and yield of improved maize in Nepal have been reported 841596 ha, 2143824 t and 2.55 t/ha respectively (MOAD, 2017). In Dang, the total area, production and yield of open pollinated improved maize varieties have been reported 16730 ha, 35133 t and 2.1 t/ha respectively. Also, 17 t seeds of open pollinated improved maize varieties have been sold from DADO, Dang with 50% subsidy in the fiscal year 2016/17 (DADO, 2017). Prime Minister Agriculture Modernization Project (PM-AMP) has selected Dang as 'maize superzone' (MOAD, 2016). Rampur Composite (recommended in 1975 for terai and mid hills), Arun 2 (recommended in 1981 for terai and mid-hills) are the commonly grown open pollinated improved varieties in Dang (DADO, 2017). This research is designed to determine the factors affecting the decision to adopt open pollinated improved maize varieties, compare the mean yield of open pollinated improved with local and hybrids and to identify the major constraints in maize production in maize superzone distirct, Dang, Nepal.

METHODOLOGY

Study area, sample size and data collection technique

Dang district was purposively selected for the study taking into account that the Prime Minister Agriculture Modernization Project (PM-AMP) has selected Dang as 'maize super zone' (MOAD, 2016). The major maize growing areas of Dang- Lamahi (23 km from DADO), Satbaria (30 km from DADO), Shantinagar (30 km from DADO) and Ghorahi (where DADO is located) were identified in consultation with District Agriculture Development Office (DADO) and Maize Super zone office, Dang. Most of these areas also have been listed as the program implementation areas of Maize Super zone, PMAMP (PMAMP, 2016). From each area, samples were selected through simple random sampling in proportionate of their sampling frame. A total of 100 households were surveyed. Primary data were collected through a pre-tested interview schedule, focus group discussions and key informant interviews. Secondary data were collected from relevant publication of government offices such as Ministry of Agricultural Development (MOAD), Central Bureau of Statistics (CBS), National Planning Commission (NPC) and so on.

Determination of factors affecting the decision to adopt improved maize varieties

A probit regression model was used to analyze the effect of different variables on decision to adopt open pollinated improved maize varieties. To investigate the factors affecting the adoption of improved technology, probit model have been found to be used used in many studies (Hattam, 2006). Fadare et al. (2014) used probit regression model to study the factors affecting adoption decision of improved maize varieties in Nigeria. In a like manner, Kafle

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(2010) also used probit model to analyze the factors affecting the decision to adopt improved maize varieties in developing countries. In contrary to this, Kafle and Shah (2012) used the binary logistic regression to identify the socio-economic and farm characteristics affecting the decision in adoption of hybrid maize varieties. The probit model is often used when a choice is to be made between two alternatives; in this study, decision to either adopt (or not adopt) improved maize varieties. From the perspective of an economist, an individual ***i*** makes a decision to adopt if the utility associated with that adoption choice (V_{1j}) is higher than the utility associated with decision not to adopt (alternative choice), (V_{0j}). Koop (2003) stated that the difference in utilities of the two alternative choices is stated as $Y_j^* = V_{1j} - V_{0j}$ and the econometric specification of the model is given in its latent as:

$$Y_j^* = X_j\beta + e_j$$

Where Y_j^* is an unobserved (latent) random variable that defines farmer's binary (adoption) choices, X_j are sets of explanatory variables associated with individual j. β is a vector of coefficients associated with the explanatory variables while e_j represents the random error terms defined as: $e \sim N(0, 1)$. The relationship between the unobserved variable Yj^* and the observed outcome (Yj) can be specified as:

$$Yj = 1, \text{ if } Yj^* \geq 0$$

$$Yj = 0, \text{ if } Yj^* < 0$$

Probit model has the characteristic feature; the effect of independent variables on dependent variables is non-linear. It is a statistical model which aims to form a relation between probability values and explanatory variables ensuring that the probability value remains between 0 and 1. For the statistical analysis of the model, STATA software package was used.

In this study, adoption of open pollinated improved maize varieties will be based on an assumed underlying utility function. According to this theory, open pollinated improved maize varieties will be adopted by the farmer, if the utility obtained from the open pollinated improved maize varieties exceeds that non-adoption. The farmer's behaviour towards open pollinated improved maize varieties is described by the following equations;

$$\text{Prob}(Y^*_i) = \sigma_0 + \Sigma\, \delta_n X_i + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation } 1$$

$$\text{Prob}(\text{Adopt}=1) = \Upsilon' K + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation } 2$$

Where,

Y^*_i = A latent variable representing the propensity of a farm household i to adopt open pollinated improved maize varieties (1 if farmer adopt open pollinated improved maize and 0 otherwise)

X_i = K= the vector of households' socio-economic and farm characteristics and variables that influence the adoption decision

σ_0, δ_n = parameters to be estimated

ε_i = error term of the i^{th} farm households

i = 1, 2, 3, … n farm households

The probit model specified in this study to analyze the factors affecting farmers' decisions to adopt open pollinated (OP) improved maize varieties

Pr (adopting OP improved varieties =1) = f (b_0+ b_1 X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9)

where, Pr = Probability score of adopting OP improved varieties

X_1= Major occupation (Dummy)

X_2= Ethnicity (Dummy)

X_3= Gender of the household head (decision maker) (Dummy)

X_4= Area under open pollinated improved maize (in Ha.)

X_5= Number of visits of agricultural technician to farmer's field

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X_6= Number of visits by farmer to agrovets
X_7= Input support (dummy)
X_8= Seed_source (dummy)
X_9= Credit access (dummy)
$b_1, b_2 \ldots b_9$ = Probit coefficient, b_0 = Regression coefficient

Table 1. Statistical description of the variables used in the probit regression model.

Variables	Description	Value	Expected sign
Major occupation	Major occupation of the household	Agriculture= 1, otherwise = 0 (Dummy)	+
Ethnicity	Ethnicity of the household	Brahmin/Chettri = 1, otherwise = 0 (Dummy)	+ /-
Gender of the HH	Gender of the household head (decision maker)	Male = 1, otherwise = 0 (Dummy)	+ /-
Area under OP maize	Area under open pollinated improved maize	Hectare (ha)	+
No. of visits of Ag. technician	Number of visits of agricultural technician to farmer's field	Times (in number)	+
No. of visits to agrovet	Number of visits by farmer to agrovets	Times (in number)	+ /-
Input support	Input support from anywhere	Yes=1, otherwise = 0 (Dummy)	+
Seed source	Seed source for the farmers	DADO/cooperatives = 1, otherwise = 0 (Dummy)	+
Credit access	Credit access for the farmers	Yes=1, otherwise = 0 (Dummy	+

Mean comparison of productivity of local, OP improved and hybrid varieties

An unpaired t test with equal variances was used to compare the productivity of OP improved and local varieties of maize. T-test was again used to compare the productivity of OP improved and hybrid varieties. Before applying t test, multivariate normality test was done to check the normality of the data. Statistical packages for Social Sciences (SPSS) was used for data analysis.

Problems/constraints associated with maize production

Opinions regarding the major problems associated with maize production were asked of the respondents and ranked on the basis of their priority to different problems. Indexing/Scaling technique was applied to construct an index for prioritizing the problems as per farmers' perception using MS-Excel. Miah (1993) stated that the scaling techniques provide the direction and extremity attitude of the respondents towards any proposition. On the basis of responded frequencies, weighted indexes were calculated for the analysis of farmer's perception on the extent of production problems. Farmer's perception to the different production problems were ranked by using five point scales. The formula used to determine the index for intensity of various problems is:

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$$I_{prob} = \sum \frac{Sifi}{N}$$

where, I_{prob} = index value for intensity of problem
$\sum$= summation
S_i = scale value at i^{th} intensity/severity
f_i= frequency of the i^{th}severity
N= total no. of the respondents = $\sum f_i$
where, $\mathbf{I_{prob}}$ = index, $0 < I < 1$

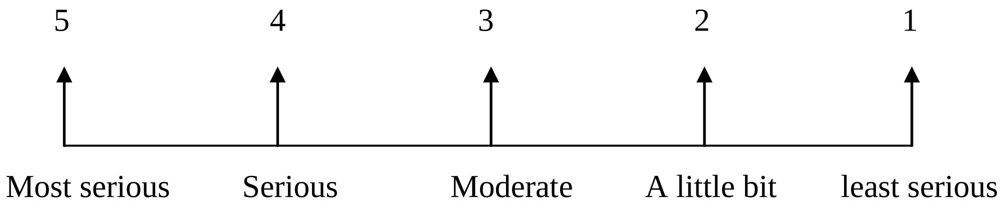

Figure 1. Scale of rating

RESULTS AND DISCUSSION

Determination of factors affecting the decision to adopt improved maize varieties

According to Rogers and Shoemaker (1971), adoption is the mental process through which an individual passes from the first stage of awareness or knowledge of an innovation to a decision to adopt or reject and then confirmation of this decision. To identify the factors affecting the decision to adopt OP improved maize varieties, a probit model of regression was used. Among the 100 respondents, the binary response was coded as; OP improved maize adopters =1 and 0 otherwise. The Wald test (LR chi^2) for the model indicated that the model has good explanatory power at the 1% level. This means that all the explanatory variables included in the model jointly influence farmer's probability of adoption of OP improved maize varieties. The probit model estimation gave a pseudo R^2 of 0.44, which implies that the variables included in the model are able to explain about 44 percent of the probability of farmers' decisions to adopt or not to adopt OP improved maize varieties. The measure of goodness of fit here concluded that the probit model employed had integrity and hence is appropriate.

Table 2. Factors affecting the decision to adopt OP improved maize varieties.

Variables	Coefficients	P>|z|	Standard error	dy/dx[b]	S.E[b]
Major occupation (Agriculture =1)	-.4631	0.262	.4126	-.1379	.1104
Ethnicity (Brahmin/Chettri =1)	.9454***	0.007	.3488	.3130	.1134
Gender of the household head (male =1)	-1.8256**	0.040	.8882	-.3081	.0668
Area under OP maize (Ha.)	1.8886***	0.002	. 6094	.6086	.1925
No. of visits of Ag. technician (times in number)	.2795	0.151	. 1946	.0901	.0641
Number of visits to agrovets (times in number)	-.2766**	0.045	.1378	-.0892	.0444
Input support (yes= 1)	.0364	0.926	.3901	.0117	.1248
Seed source (DADO/cooperatives= 1)	1.3436***	0.000	.3683	.4240	.1072
Credit access (yes= 1)	.2507	0.497	.3690	.0815	.1205
Constant	.4119	0.671	.9692	-	-

*** Significant at 1% level ;** Significant at 5% level **;** * Significant at 10% level
[b]Marginal change in probability evaluated at the sample means

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Summary Statistics	
Number of observation(N)	100
Log likelihood	-36.481983
LR chi^2 (9)	56.53*** (Prob> chi^2 =0.0000)
Pseudo R^2	0.44
Predicted probability (adoption)	0.7432264
Goodness of fit test	Pearson chi^2 (85) = 221.90 .Prob> chi^2 = 0.0000

Source: Field survey, 2017

Probit regression analysis showed that five variables were statistically significant for the decision to adopt OP improved varieties of maize. They were; ethnicity, gender of the household head, area under improved maize, number of visits by farmer to agrovets and seed source (Table 2). For the interpretation of the model, marginal effects were driven from the regression coefficients, calculated from the partial derivatives as a marginal probability. The interpretation is shown in Table 2.

Ethnicity being Brahmin/Chettri (dummy) was found to be highly significant (at 1% level of significance) and positively related to the adoption of OP improved maize varieties. The probability of adoption of OP improved maize increases by 31% for the farmers whose ethnicity is Brahmin/Chettri as compared to the farmers having their ethnicity otherwise (Table 2). In addition, the study revealed that the majority of the farmers belong to caste Brahmin/Chettri (59%). Also, it has been revealed that, of the total farmers having principal occupation agriculture, majority were Brahmin/Chettri (56%). Sengupta (1970) stated that the farmers having agriculture as their primary occupation were found to be showing the higher adoption behavior. Apart from this, it has been reported that the level of adoption was higher among the farmers of intermediate castes to whom farming was a traditional occupation than among the farmers who belongs to higher ritual status (Alam, 1965).

Similarly, area under improved maize was found to be highly significant (at 1% level of significance) and positively related to the adoption of OP improved maize varieties. A unit increase in area of improved maize would increase the probability of adoption of OP improved maize varieties by 61% (Table 2). Though a unit of improved maize cultivated area is increased within a farm, it might have positive multiplier effects in adoption of improved varieties by other farms. The size of cultivated land was found to have positive and significant effect on the adoption of new agricultural technology (Gogoi & Gogoi, 1989). In addition, Olowu et al. (1988) stated that the farmers who have large scale cultivation are willing to take risk associated with the adoption of new technology.

Unlike this, household head (decision maker) being male (dummy) was found to be significant (at 5% level of significance) but negatively related to the adoption of OP improved maize varieties. The probability of adoption of OP improved maize varieties decreases by 31% for the households having male household head as compared to households having female household head (Table 2). Perhaps, male leaders might have focused on hybrids for higher productivity and females might have preferred improved for the reason that this year produce could be kept and used for next year seeds in a case of improved varieties; oftentimes, females shows saving nature. In a like manner, Kafle and Shah (2012) reported that the male headed household positive influences on the adoption of hybrid maize varieties than others. Aregu et al. (2011) also reported that the government has encouraged women participation and gender inclusion in the workshop and training related to seed production, nursery management and fertilizer treatments. In a like manner, Tavya et al.

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(2013) stated that it would be an encouragement to increase the agricultural productivity if technological innovation is properly understood from the gender perspective.

Furthermore, the number of visits by farmers to agrovets was found to be significant but negatively related to the adoption of OP improved maize at 5% level of significance. A unit increase in the number of visits to agrovet decreases the probability of adoption of OP improved maize varieties by 8% (Table 2). This might be due to the reason that the agrovets are motivating the farmers for adopting the multinational hybrids because of the high benefits associated with the sale of those hybrids. There are 93 agrovets in Dang district. The hybrid maize varieties mostly available in the agrovets are: Rajkumar, Nutan, Pioneer 3396, Pioneer 3522, Bioseed 679, Kanchan, Subarna and Aditya (DADO, 2017). Also, it has been revealed that the private institutions such as agrovets are the prime sources of hybrid maize seeds for the farmers. Agrovet was found to be principal supplier of hybrid seeds, supplying 90.7% of the total hybrid seeds reaching to farmers (Kafle & Shah, 2012). Lastly, seed source being DADO/cooperatives (dummy) was found to be highly significant (at 1% level of significance) and positively related to the adoption of OP improved maize varieties. For the households, seed source being DADO/cooperatives, the probability of adoption of OP improved maize varieties increases by 42% as compared to the households, seed source being otherwise (Table 2). The DADO and cooperatives might have given emphasis for the adoption of the improved varieties with the subsidy scheme given by the government of Nepal. Also, the study revealed that the majority of the farmers of the study area buy seeds from DADO/cooperatives (53%). And of them, nearly 85% of the farmers have cultivated seeds of improved maize varieties in their field. It has been reported that 17 Mt. seeds of open pollinated improved maize varieties was sold from DADO, Dang with 50% subsidy in the fiscal year 2016/17 (DADO, 2017). Besides, DADO is the authorized government agricultural institution having the clear mandate of providing extension services to the farmers. Kafle (2000) revealed that that there exists a positive influence of extension contact on adoption of improved maize varieties.

Mean comparison of productivity of OP improved and local varieties

Multivariate normality test showed that the two samples are normally distributed (Doornik-Hansen chi2(4)= 0.835, Prob>chi2= 0.9336). Two-sample t test with equal variances was carried out to compare the productivity means. The mean productivity of OP improved maize varieties (2.28 t/ha) in Dang was found to be significantly higher (at 1% level of significance) compared to local varieties (1.74 t/ha) (Table 3). It would be a wise decision to substitute the local varieties by improved ones for higher productivity. Paudyal (2001) reported that the trend of cultivating local varieties has decreased in the mid hills of Nepal. In a like manner, Lamichhane et al. (2015) revealed that the improved varieties (Rampur composite, Arun 2, Manakamana 6) are getting popularity in the western hills; this indicated the positive attitude of maize growing farmers in adopting the improved varieties substituting the local.

Table 3. Mean comparison of productivity of OP improved and local variety.

Variables	Obs	Mean	Std. Err.	Std. Dev.	t value
Productivity of OP improved varieties	68	2.2846	0.0530	0.4369	4.5994***
Productivity of local varieties	15	1.7413	0.0723	0.2800	
Combined	83	2.1864	0.0507	0.4621	
Diff		0.5432	0.1181		

*** Significant at 1% level Source: Field Survey, 2017

Moreover, government should bring a policy giving aggressive subsidy in inputs (seeds and fertilizers) allied with access to technology and training to the farmers in adoption of

improved maize varieties. No doubt, this could substitute the local varieties to a greater extent in terms of area coverage which ultimately leads to increased productivity and adoption.

Mean comparison of productivity of hybrid and OP improved maize varieties

Test for multivariate normality was carried out to check whether the two samples are normally distributed or not. This normality test showed that the two samples are normally distributed (Doornik-Hansen chi2(4)= 0.592, Prob>chi2= 0.9640). Two-sample t test with equal variances was again used to compare the productivity means. The mean productivity of hybrid maize varieties (3.81 t/ha) in Dang was found to be significantly higher (at 1% level of significance) compared to OP improved varieties (2.28 t/ha) (Table 4). National Maize Research Program (NMRP) should orient their efforts in developing the high yielding hybrids to increase the maize productivity in Nepal. In addition, appropriate extension services are needed for the adoption of developed hybrids. Timsina et al. (2016) also used two independent samples t- test to compare the yield of maize in Kavre and Lamjung districts of Nepal, which revealed that the productivity of maize was significantly higher in kavre (4.63 t/ha) compared to Lamjung (3.2 t/ha). In addition, the average yield of maize (both hybrid and open pollinated improved improved varieties) in Kavre was calculated 4.63 t/ha, while the average yield of only hybrid varieties was calculated 5.06 t/ha; this showed the superiority of hybrids over improved in terms of yield. Also, the yield of hybrid maize was found to be significantly higher in Kavre (4.63 t/ha) compared to Lamjung (3.2 t/ha).

Table 4. Mean comparison of productivity of hybrid and OP improved variety.

Variables	Obs	Mean	Std. Err.	Std. Dev.	t value
Productivity of hybrid varieties	17	3.8112	0.2643	1.0899	9.0965***
Productivity of OP improved varieties	68	2.2846	0.0530	0.4369	
Combined	85	2.5899	0.0943	0.8694	
Diff		1.5266	0.1678		

*** Significant at 1% level Source: Field Survey, 2017

Assessment of problems/constraints associated with the maize production

From the survey conducted among the maize growers, lack of availability of quality seeds and fertilizers was ranked as the major problem followed by lack of advanced technology and training, when questioned about the problems associated with the maize production. Similarly, lack of proper interaction between farmers and extension service providers, infestation of disease and pest and lack of proper irrigation and drainage facilities were the third, fourth and fifth problems respectively as per farmer’s ranking (Table 5). Paudyal (2001); Shrestha and Timsina (2011) also stated that the yield is significantly affected by seed quality, infestation of disease and pest and availability of irrigation. Similarly, Hailu (1992) stated that the lack of availability of quality seeds including other inputs (fertilizers, farm machinery) are the main bottlenecks in increasing maize production and productivity. In addition, Rogers (2003) and Hintze et al. (2003) reported that the adoption of maize seed production, increment in maize production and income are assisted by the availability of technical assistance and adequate irrigation facilities.

Farmers should be provided the environment for interaction and discussion on various problems related to crop production. It has been revealed that the farmers who have joined the Farmer's Field School (FFS) were more forward in identification and prioritization of the problems and solutions themselves (Adhikari, 2005).

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Table 5. Problems associated with the maize production.

S. N	Problems	Most serious	Serious	Moderate	A little bit	Least	Index value	Rank
1	Lack of quality seeds and fertilizers	54	31	4	11	0	0.86	I
2	Lack of advanced technology and training	20	47	22	7	4	0.74	II
3	Lack of proper interaction between farmers and extension service providers	18	13	45	22	2	0.65	III
4	Incidence of diseases and insects pests	8	1	12	51	28	0.42	IV
5	Lack of proper irrigation and drainage	0	7	18	9	66	0.33	V

Source: Field Survey, 2017

CONCLUSION

Adoption of the OP improved maize varieties could be promoted by mobilizing the innovative female adopters in the community. Agrovets might be motivating the farmers for adopting multinational companies' hybrids; this might be due to either realization of high benefits in selling those hybrids or due to the unavailability of subsidy seeds of OP improved maize varieties. Government should give dealership to the registered agrovets with easy procedure for selling the subsidy seeds of OP improved maize varieties. The productivity of OP improved maize varieties in Dang was found to be significantly higher than local maize varieties. Ministry of Agricultural Development should bring a policy giving aggressive subsidy in inputs to the farmers in adoption of OP improved maize varieties; this could substitute the local varieties to a greater extent in terms of area coverage which ultimately leads to increased adoption. Also, there is a need of high yielding hybrid maize varieties to be developed, released and made available in Nepal. Moreover, the difference between the productivity of OP improved and hybrid maize varieties was found to be highly significant in this study which concluded that hybrids are significantly superior to OP improved varieties in terms of productivity. National Maize Research Program (NMRP) should orient their efforts in developing the high yielding hybrid varieties in Nepal to increase the maize productivity. In addition, appropriate extension services are needed for the adoption of developed hybrids. Lacking proper access to quality seeds, advanced technology and training, effective extension services, appropriate plant protection measures, irrigation and drainage were identified as the major problems associated with the maize production ranked from first to fifth priority respectively; an efficient action plan need to be formulated which could orient towards increased maize production and productivity in maize super zone district- Dang and ultimately Nepal.

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AUTHORS' CONTRIBUTION

S. S. designed the research methodology, analyzed data and wrote the paper in consultation with Y.N. G. and D. D. assisted S. S. in questionnaire design, conducting field survey, data

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collection and data entry. S. S. revised the article for the final approval of the version to be published.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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Soil physico-chemical characterization in the different soil layers of National Maize Research Program, Rampur, Chitwan, Nepal

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ABSTRACT

Soil pit digging and their precise study is a decision making tool to assess history and future of soil management of a particular area. Thus, the present study was carried out to differentiate soil physico-chemical properties in the different layers of excavated pit of the National Maize Research Program, Rampur, Chitwan, Nepal. Eight pits were dug randomly from three blocks at a depth of 0 to 100 cm. The soil parameters were determined in-situ, and in laboratory for texture, pH, OM, N, P (as P_2O_5), K (as K_2O), Ca, Mg, S, B, Fe, Zn, Cu and Mn of collected soils samples of different layers following standard analytical methods at Soil Science Division, Khumaltar. The result revealed that soil structure was sub-angular in majority of the layers, whereas bottom layer was single grained. The value and chrome of colour was increasing in order from surface to bottom in the majority pits. Similarly, the texture was sandy loam in majority layers of the pits. Moreover, four types of consistence (loose to firm) were observed. Furthermore, mottles and gravels were absent in the majority layers. Likewise, soil was very to moderately acidic in observed layers of majority pits, except bottom layer of agronomy block was slightly acidic. Regarding fertility parameters (OM, macro and micronutrients), some were increasing and vice-versa, while others were intermittent also. Therefore, a single layer is not dominant for particular soil physico-chemical parameters in the farm. In overall, surface layer is more fertile than rest of the layers in all the pits.

Keywords: Chemical properties; Maize research; Physical properties; Pit study; Soil layers

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INTRODUCTION

Soil is a unique natural resource for sustaining life of human being and agricultural development in the earth (Das et al., 2009). The soil develops from the rocks, through weathering process. The rocks are possessed at lower depth of the soil layer. If we dug the soil below the surface, and started to study separately about the observed layers have a peculiar meaning for their development as well adopted soil management practices. Therefore, pit digging and there details study plays important role for enhancing knowledge about the specific soil system as well helps to make sustainable land use planning. In other word, the differentiation of different layers in the excavated pit, and their systematic study provides history and future of an area for economic production through sustainable soil management (Brady & Weil, 2004).

The different layers have different physico-chemical properties. A single layer may not be superior for all the parameters. The different observations of layers like depth, distinctness of boundary and their topography, structure, consistence, colour, abundance of mottles, gravels, roots etc. can be determined in-situ condition. The colour is composed of hue, value and chrome (Goswami et al., 2009). Hue is considered as the dominant spectral colour such as red, yellow, green, blue and violet, whereas value is the lightness or darkness of colour ranging from 1(dark) to 8 (light), and chrome is the purity or strength of colour varying from 1 (pale) to 8 (bright) (Mikkelsen et al., 2009). Moreover, soil consistence referred to the resistance of soil materials to deformation or compression (Panda, 2010). Similarly, texture, Soil reaction (pH), organic matter, macro and micronutrients content in the different soil layers can be determined in the laboratory. These parameters symbolize how the human beings are using the soils, and how natural processes are running inside the soil which we cannot observe directly in the surface.

Nepal Agricultural Research Council (NARC) was established to strengthen agriculture sector in the country through agriculture research. In terms of area and production, maize (*Zea mays* L.) is a second most important crop after rice (*Oryza sativa* L.) in Nepal (KC, 2015).National Maize Research Program, Rampur, Chitwan, Nepal is an important wing among the research farms of NARC, in order to generate appropriate maize production technologies for the Nepal. Studies (in-situ and laboratory) related to different soil layers through pit digging in the different blocks of National Maize Research Program, Rampur, Chitwan, Nepal are not done yet. Previously, studies are only focused towards surface layer's soil fertility assessment and mapping only. Keeping these facts, the present study was conducted with the objective to determine soil physico-chemical properties in the different soil layer of crop growing blocks (seed production, agronomy and research) of National Maize Research Program, Rampur, Chitwan, Nepal. This may provide valuable information relating maize and other crop's research improvement through sustainable planning in the particular block.

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MATERIALS AND METHODS

Study Area Descriptions

The study was carried out at National Maize Research Program, Rampur, Nepal (Figure 1). The research farm is situated at the latitude 27°40'36" and longitude 84°21'24" as well altitude 173masl. The studied area lies in inner terai region, and near to longest river (Naryani) of Nepal. Moreover, humid and sub-tropical with cool winter (2 to 3^{o}C) and hot summer (43^{o}C) climatic condition. The annual rainfall is >1500 mm, where monsoon period (>75% of annual rainfall) starts from mid-June to mid-September (Nepal Agricultural Research Council [NARC], 2007).

Field Study and Soil Sampling

The total eight pits were dug at depth 0 to 100 cm in different sites of National Maize Research Program, Rampur, Nepal during March 2015 (Figure 1). Four pits were dug in Seed production block; two pits were in Agronomy block and rest two pits were in Research block. The positioning of the pits was recorded using a handheld GPS receiver (Table 1). Soil physico-chemical characterizations were done in-situ as well in the laboratory. During in-situ study each layer were observed for depth, boundary (distinctness), boundary (topography), soil colour, structure (type), consistence (dry/moist/wet), mottles (abundance), Roots (abundance) and gravels (abundance). The soil colour was determined by Munshell-colour chart. Soil samples were collected from each layer for the laboratory analysis of different physico-chemical properties.

Laboratory Analysis

The collected soil samples were analyzed at Soil Science Division, Khumaltar laboratory. The different soil parameters tested as well as methods adopted to analyze is shown on the Table 2.

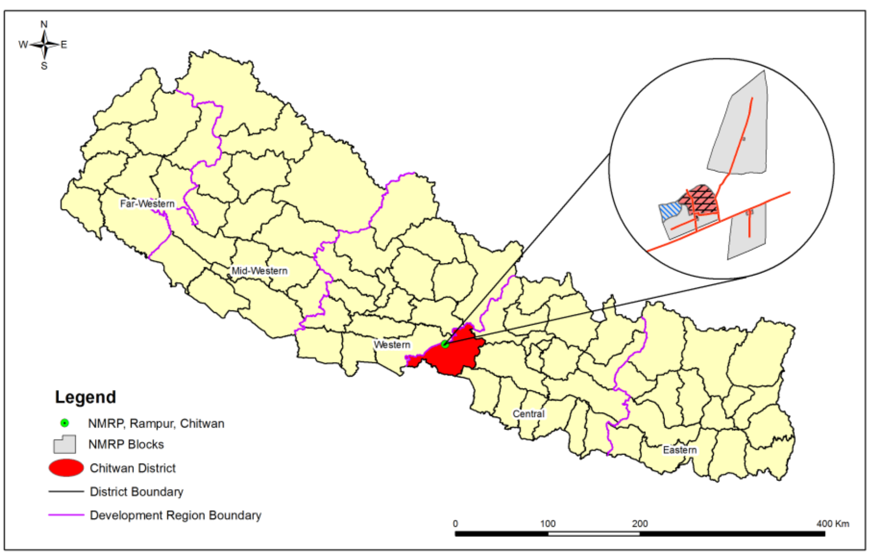

Figure 1. Location Map of National Maize Research Program, Rampur, Chitwan, Nepal

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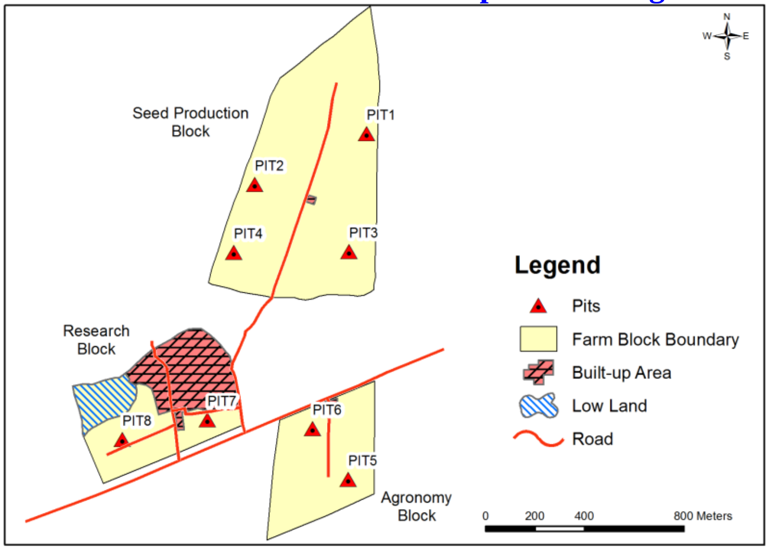

Figure 2. Distribution of Pit Sampling Points in the Different Blocks of National Maize Research Program, Rampur, Chitwan, Nepal

Table 1. Global Positioning of the Pits dug in National Maize Research Program, Rampur, Chitwan, Nepal

SN	Pit No	Latitude	Longitude	Elevation
1	1	27°40’53”	84°21’28”	177.54masl
2	2	27°40’46”	84°21’40”	176.76masl
3	3	27°40’38”	84°21’26”	177.08masl
4	4	27°40’37”	84°21’40”	170.92masl
5	5	27°39’08”	84°21’27”	187.78masl
6	6	27°39’14”	84°21’21”	171.28masl
7	7	27°39’15”	84°21’06”	173.29masl
8	8	27°39’12”	84°21’53”	179.40masl

Table 2. Parameters and Methods Adopted for the Laboratory Analysis at Soil Science Division, Khumaltar

S.N.	Parameters	Unit	Methods
1.	**Physical**		
	Soil texture		Hydrometer (Bouyoucos, 1927)
	Soil structure		Field-feel
2.	**Chemical**		
	Soil pH		Potentiometric 1:2 (Jackson, 1973)
	Organic matter	%	Walkely and Black (Walkely and Black, 1934)
	Total N	%	Kjeldahl (Bremner and Mulvaney, 1982)
	Available P (as P_2O_5)	mg/kg	Olsen’s (Olsen et al., 1954)
	Available K (as K_2O)	mg/kg	Ammonium acetate (Jackson, 1967)
	Available Ca	mg/kg	EDTA Titration (El Mahi et al.,1987)
	Available Mg	mg/kg	EDTA Titration (El Mahi et.al.,1987)
	Available S	mg/kg	Turbidimetric (Verma, 1977)
	Available B	mg/kg	Hot water (Berger and Truog, 1939)
	Available Fe	mg/kg	DTPA (Lindsay and Norvell, 1978)
	Available Zn	mg/kg	DTPA (Lindsay and Norvell, 1978)
	Available Cu	mg/kg	DTPA (Lindsay and Norvell, 1978)
	Available Mn	mg/kg	DTPA (Lindsay and Norvell, 1978)

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RESULTS AND DISCUSSION

Soil Physico-chemical Characterization in the Different Soil Layer of Seed Production Block

The field observed and laboratory data pertaining different soil layers (0 to 100cm) of seed production block is shown in the Table 3 to 6.

In-situ Observations

There were two soil layers in three pits, while three layers contains in one pit (pit 3). The depth of soil layers in all the pits was different. The distinctness of the boundary indicates thickness between two adjacent layer (FAO, 2006).The distinctness of the boundaries between the layer was abrupt (<2 cm) in all the pits. Similarly, topography refers shape of the boundary (FAO, 2006). Two types of topography smooth (2 pits) and wavy (2 pits) were determined. The colour was different in the different soil layers of the pits. Hue (10YR) was similar in observed layers of all the pits, value was constant in all the pits except pit 1, and chrome was increasing from surface to bottom layers of all the pits.

The consistence depends upon the nature and availability of clay, organic matter and moisture content of the soil. The consistence in the majority of layers was friable. This indicates this block is suitable for agricultural purposes. Mottles are spots of various colours dispersed with the dominant colour of the soil (FAO, 2006). Mottles were absent in observed layers of all the pits. This argues good drainage status, and ground water table is far below the studied depth. Similarly, amounts of roots were denser in surface layer than lower layer in all the pits. Likewise, gravels were also absent in all the layers of the pits. Absence of gravels in the layers signifies, there are no obstacles for root growth, and uptake of water and nutrients from soil.

Laboratory Observations

The acidic pH was observed in the observed layer of all the pits. Similarly, upper layer is more acidic than other layers except in pit 1. Upper layer is more acidic than others might be due to more influence of crop production activity in this layer. Consistent result was also obtained during surface (0 to 20cm) soil fertility assessment and mapping of the seed production block of National Maize Research Program, Rampur, Chitwan, Nepal (Khadka et al., 2016). The different agricultural activities running during crop production enhances soil acidity in long-term (Havlin et al., 2010).The organic matter, total nitrogen, available phosphorus (as P_2O_5), available potassium (as K_2O), available sulphur, available boron, available iron, available zinc, available copper and available manganese content was decreasing in order from top to bottom layers in majority of the pits. Whereas, the pattern of available calcium and magnesium was intermittent. The textural class was sandy loam in all the layers of pits. The satisfactory condition in soil fertility at upper layer of all the pits indicates current soil fertility management practice is sustainable for the crop growth and development in the seed production block.

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Table 3. Soil Physico-Chemical Characterization in the Different Soil Layers of Seed Production Block (Pit 1)

Description	Layer	
	First	Second
Depth (cm)	0 to 74	74 to 100
Boundary (distinctness)	abrupt	
Boundary (topography)	smooth	
Colour	10YR 4/3, dark brown	10YR 5/6, yellowish brown
Structure (types)	sub-angular blocky	single grained
Consistence (moist)	friable	very friable
Mottles	absent	absent
Roots (abundance)	few	very few
Gravels	absent	absent
pH	5.9	5.35
OM (%)	3.3	1.5
N (%)	0.13	0.08
P_2O_5 (mg/kg)	9.81	118.14
K_2O (mg/kg)	69.60	9.60
Ca (mg/kg)	120	200
Mg (mg/kg)	112.8	76.8
S (mg/kg)	0.2	0.1
B (mg/kg)	0.54	0.51
Fe (mg/kg)	7.82	3.32
Zn (mg/kg)	0.08	0.06
Cu (mg/kg)	0.34	0.24
Mn (mg/kg)	2.18	1.86
Sand (%)	63	71
Silt (%)	28.2	22.2
Clay (%)	8.8	6.8
Texture Class	sandy loam	sandy loam

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Table 4. Soil Physico-Chemical Characterization in the Different Soil Layers of Seed Production Block (Pit 2)

Description	Layer	
	First	Second
Depth (cm)	0 to 30	30 to 100
Boundary (distinctness)	abrupt	
Boundary (topography)	smooth	
Colour	10YR 3/2, very dark grayish brown	10YR 3/3, dark brown
Structure (types)	sub-angular blocky	sub-angular blocky
Consistence (moist)	friable	friable
Mottles	absent	absent
Roots (abundance)	few	few
Gravels	absent	absent
pH	5.29	5.57
OM (%)	2.9	3.6
N (%)	0.12	0.14
P_2O_5 (mg/kg)	76.73	8.07
K_2O (mg/kg)	69.60	69.60
Ca (mg/kg)	420	220
Mg (mg/kg)	124.8	136.8
S (mg/kg)	0.7	0.3
B (mg/kg)	0.50	0.51
Fe (mg/kg)	9.76	6.16
Zn (mg/kg)	0.5	0.4
Cu (mg/kg)	0.42	0.38
Mn (mg/kg)	2.14	2.36
Sand (%)	69	71
Silt (%)	22.2	20.2
Clay (%)	8.8	8.8
Texture Class	sandy loam	sandy loam

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Table 5. Soil Physico-Chemical Characterization in the Different Soil Layers of Seed Production Block (Pit 3)

Description	Layer		
	First	Second	Third
Depth (cm)	0 to 25	25 to 65	65 to 100
Boundary (distinctness)	abrupt	abrupt	
Boundary (topography)	wavy	wavy	
Colour	10YR 4/3, dark grayish brown	10YR 4/4, brown	10YR 4/4, dark yellowish brown
Structure (types)	sub-angular blocky	sub-angular blocky	single grain (dominant); sub-angular blocky (also present)
Consistence (moist)	firm	friable	friable
Mottles	absent	absent	absent
Roots (abundance)	few	few	very few
Gravels	absent	absent	absent
pH	4.77	5.21	5.17
OM (%)	4.5	2.8	1.8
N (%)	0.17	0.12	0.09
P_2O_5 (mg/kg)	102.45	19.18	18.96
K_2O (mg/kg)	153.62	81.61	57.59
Ca (mg/kg)	360	140	200
Mg (mg/kg)	172.8	148.8	100.8
S (mg/kg)	1.1	0.3	0.1
B (mg/kg)	0.75	0.67	0.33
Fe (mg/kg)	14.8	4.76	3.52
Zn (mg/kg)	0.42	0.3	0.27
Cu (mg/kg)	0.58	0.32	0.22
Mn (mg/kg)	5.92	2.06	1.62
Sand (%)	71	57	61
Silt (%)	20.2	34.2	32.2
Clay (%)	8.8	8.8	6.8
Texture Class	sandy loam	sandy loam	sandy loam

Table 6. Soil Physico-Chemical Characterization in the Different Soil Layers of Seed Production Block (Pit 4)

Description	Layer	
	First	Second
Depth (cm)	0 to 20	20 to 100
Boundary (distinctness)	abrupt	
Boundary (topography)	wavy	
Colour	10YR 4/2, dark grayish brown	10YR 4/3, brown
Structure (types)	sub-angular blocky	sub-angular blocky (dominant), single grain (also present)
Consistence (moist)	firm	very friable
Mottles	absent	absent
Roots (abundance)	few	few
Gravels	absent	absent
pH	4.67	5.0
OM (%)	4.6	2.7
N (%)	0.17	0.12
P_2O_5 (mg/kg)	129.92	12.86
K_2O (mg/kg)	141.61	63.62
Ca (mg/kg)	340	80
Mg (mg/kg)	76.8	100.8
S (mg/kg)	0.7	0.2
B (mg/kg)	0.92	0.32
Fe (mg/kg)	15.94	5.72
Zn (mg/kg)	0.48	0.45
Cu (mg/kg)	0.5	0.38
Mn (mg/kg)	2.78	2.42
Sand (%)	73	61
Silt (%)	20.2	30.2
Clay (%)	6.8	8.8
Texture Class	sandy loam	sandy loam

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Soil Physico-Chemical Characterization in the Different Soil Layer of Agronomy Block

The field observed and laboratory data showing different soil layers (0 to 100cm) of Agronomy block is shown in the Table 7 and 8.

In-situ Observations

The number of soil layer and their depth was different in all the pits (Table 7; Table 8). The distinctness of the boundaries between the layers was clear (2 to 5 cm) and gradual (5 to 15 cm). Similarly, topography of boundary was smooth and wavy. Similar to seed production block, hue (10YR) was similar in observed layers of all the pits, while value was more in bottom layer than surface layer, and chrome was more or less similar in pit 5 but in pit 6 increasing towards bottom layers.

Regarding consistence, similar to seed production block, majority of the layers were friable, where bottom layers were more friable than surface layer. This also indicates this block is also suitable for the agricultural purpose. Mottles were present in all the layers of pits, except two above layer of pit 5. The abundance of mottles was few (2 to 5%) and common (5 to 15%). This indicates slightly poor drainage status, and ground water table is nearer to the studied depth. Furthermore, abundance of roots was more in surface layer than bottom layer in all the pits. Likewise, gravels were absent in majority of the layers of pits, but few amount was observed in bottom layer of pit 5.

Laboratory Observations

Similar to seed production block soil pH was acidic in observed layer of all the pits. Corresponding result was also obtained during soil fertility assessment and mapping of agronomy block of National Maize Research Program, Rampur, Chitwan, Nepal at 0 to 20 cm depth (Khadka et al., 2016). The bottom layer of both pits was slightly acidic, while other layers were moderately acidic in nature. Upper layer is more acidic than others might be due to more influence of crop production activity in above layers. The organic matter, total nitrogen, available phosphorus (as P_2O_5), available potassium (as K_2O), available sulphur, available boron, available iron, available zinc and available copper content was decreasing in order from top to bottom majority layers in both pits. Whereas, the pattern of available calcium and magnesium was intermittent in order form top to bottom layers, but higher content in surface layer of both pits. Correspondingly, the pattern of available manganese was intermittent in all the layers from top to bottom but higher in bottom layer than others in both pits. Regarding soil texture, the proportion of sand was increasing in order from top to bottom layers, while silt and clay proportion decreasing in order. Four types textural class (sandy loam, loam, loamy sand and sand) was observed in the different layers of both pits.

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Table 7. Soil Physico-Chemical Characterization in the Different Soil Layers of Agronomy Block (Pit 5)

Description	Layers			
	First	Second	Third	Fourth
Depth (cm)	0 to 20	20 to 40	40 to 70	70 to 100
Boundary (distinctness)	gradual	gradual	clear	
Boundary (topography)	wavy	smooth	smooth	
Colour	10YR 3/2, very dark grayish brown	10YR 3/3, dark brown	10YR 6/2, light brownish gray	10 YR 6/2, light brownish gray
Structure (types)	angular blocky	sub-angular blocky	sub-angular blocky	single grained
Consistence (moist)	firm	friable	friable	loose
Mottles	absent	absent	few	common
Roots (abundance)	few	few	very few	absent
Gravels	absent	absent	absent	few
pH	5.61	5.78	5.94	6.27
OM (%)	4.6	3	0.9	0.6
N (%)	0.17	0.13	0.06	0.06
P_2O_5 (mg/kg)	8.50	0.58	0.54	0.65
K_2O (mg/kg)	51.61	39.60	39.60	27.59
Ca (mg/kg)	420	220	160	200
Mg (mg/kg)	328.8	52.8	88.8	52.8
S (mg/kg)	2.1	0.9	0.6	0.6
B (mg/kg)	0.46	0.40	0.43	0.08
Fe (mg/kg)	65.9	12.46	5.6	7.2
Zn (mg/kg)	0.48	0.08	0.086	0.046
Cu (mg/kg)	2.7	0.64	0.22	0.1
Mn (mg/kg)	5.3	0.34	0.5	6.2
Sand (%)	51	61	47	89
Silt (%)	38.2	30.2	44.2	4.2
Clay (%)	10.8	8.8	8.8	6.8
Texture Class	loam	sandy loam	loam	sand

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Table 8. Soil Physico-Chemical Characterization in the Different Soil Layers of Agronomy Block (Pit 6)

Description	Layers		
	First	Second	Third
Depth (cm)	0 to 20	20 to 60	60 to 100
Boundary (distinctness)	clear	clear	
Boundary (topography)	wavy	wavy	
Colour	10YR 5/2, grayish brown	10YR 5/3, brown	10YR 6/6, brownish yellow
Structure (types)	sub-angular blocky	sub-angular blocky	single grained
Consistence (moist)	firm	friable	loose
Mottles	few	few	common
Roots (abundance)	few	few	very few
Gravels	absent	absent	few
pH	5.83	5.78	6.24
OM (%)	2.3	1.6	0.5
N (%)	0.11	0.09	0.05
P_2O_5 (mg/kg)	66.27	4.58	1.31
K_2O (mg/kg)	99.60	51.61	27.59
Ca (mg/kg)	440	380	140
Mg (mg/kg)	172.8	52.8	100.8
S (mg/kg)	0.4	0.4	0.3
B (mg/kg)	1.35	0.60	0.23
Fe (mg/kg)	55.56	12.54	6.02
Zn (mg/kg)	0.4	0.14	0.06
Cu (mg/kg)	1.34	0.62	0.22
Mn (mg/kg)	3.14	3.26	6.52
Sand (%)	63.3	65.3	79.3
Silt (%)	27.9	25.9	13.9
Clay (%)	8.8	8.8	6.8
Texture Class	sandy loam	sandy loam	loamy sand

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Soil Physico-Chemical Characterization in the Different Soil Layers of Research Block

The field observed and laboratory data regarding different soil layers (0 to 100cm) of Research block is shown in the Table 9 to 10.

In-situ Observations

The number of soil layer was same but depth was different in both pits. The distinctness of the boundaries between the layer was clear (2 to 5 cm) in all the pits. Similarly, topography of the boundaries was smooth and wavy. Hue (10YR) was similar, while value and chrome was increasing in order from surface to bottom layers. The trend was consistent in chrome. Regarding consistence, two types of consistence namely firm and friable were determined, where bottom layer were more friable than surface layer. Mottles were absent in majority of the layers, except few in second and third layer of pit 7. This indicates good drainage status, and ground water table is below the studied depth. Furthermore, similar to above blocks amounts of roots were denser in surface layer than lower layer in both pits. Likewise, gravels were absent in the majority of the layers, except very few in second layers of pit 8.

Laboratory Observations

Soil pH was very acidic to moderately acidic in all the layer of both pits. Consistent result was also obtained during soil fertility assessment and mapping of research block of National Maize Research Program, Rampur, Chitwan, Nepal at 0 to 20 cm depth (Khadka et al., 2016).The organic matter, total nitrogen, available phosphorus (as P_2O_5), available potassium (as K_2O), available magnesium, available iron, available zinc, available copper and available manganese were decreasing in order from surface to bottom layers. Whereas, the pattern of available calcium, available sulphur and available boron intermittent. Regarding texture, sand content was increasing in order from top to bottom layers of pits, while silt content was decreasing in order. Furthermore, clay content was similar in one pit, while inconsistently decreasing in another pit. The textural class was sandy loam in majority of the layers, except loamy sand in third layer of pit 8.

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Table 9. Soil Physico-Chemical Characterization in the Different Soil Layers of Research Block (Pit 7)

Description	Layers		
	First	Second	Third
Depth (cm)	0 to 44	44 to 72	72 to 100
Boundary (distinctness)	clear	clear	
Boundary (topography)	smooth	wavy	
Colour	10YR 4/3, brown	10YR 5/4, yellowish brown	10YR 5/6, yellowish brown
Structure (types)	sub-angular blocky	sub-angular blocky	single grain (dominant); sub-angular blocky (also present)
Consistence (moist)	firm	firm	friable
Mottles	absent	few	few
Roots (abundance)	few	few	very few
Gravels	absent	absent	absent
pH	5.53	5.2	5.31
OM (%)	2.4	2.5	0.7
N (%)	0.11	0.11	0.06
P_2O_5 (mg/kg)	74.77	8.50	5.45
K_2O (mg/kg)	75.58	33.62	27.59
Ca (mg/kg)	460	120	140
Mg (mg/kg)	88.8	64.8	52.8
S (mg/kg)	0.5	0.2	0.6
B (mg/kg)	0.79	0.42	0.61
Fe (mg/kg)	21.78	8.06	4.14
Zn (mg/kg)	0.6	0.08	0.02
Cu (mg/kg)	1.78	0.19	0.08
Mn (mg/kg)	8.56	0.82	1.64
Sand (%)	65.3	69.3	71.3
Silt (%)	25.9	21.9	19.9
Clay (%)	8.8	8.8	8.8
Texture Class	sandy loam	sandy loam	sandy loam

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Table 10. Soil Physico-Chemical Characterization in the Different Soil Layers of Research Block (Pit 8)

Description	Layers		
	First	Second	Third
Depth (cm)	0 to 30	30 to 90	90 to 100
Boundary (distinctness)	clear	clear	
Boundary (topography)	smooth	smooth	
Colour	10YR 4/3, brown	10YR 4/4, dark yellowish brown	10YR 5/6, yellowish brown
Structure (types)	sub-angular blocky	sub-angular blocky	single grained
Consistence (moist)	firm	friable	loose
Mottles	absent	absent	absent
Roots (abundance)	few	few	very few
Gravels	absent	very few	absent
pH	5.14	5.41	5.55
OM (%)	2.3	1.7	1.3
N (%)	0.11	0.09	0.08
P_2O_5 (mg/kg)	219.29	11.55	13.95
K_2O (mg/kg)	87.59	51.61	27.59
Ca (mg/kg)	260	120	200
Mg (mg/kg)	112.8	64.8	64.8
S (mg/kg)	0.6	0.8	0.5
B (mg/kg)	0.30	0.82	0.79
Fe (mg/kg)	10.86	6.42	4.62
Zn (mg/kg)	0.88	0.04	0.004
Cu (mg/kg)	0.24	0.14	0.04
Mn (mg/kg)	2.02	0.96	0.6
Sand (%)	71.3	75.3	81.3
Silt (%)	19.9	17.9	11.9
Clay (%)	8.8	6.8	6.8
Texture Class	sandy loam	sandy loam	loamy sand

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CONCLUSION

The numbers of layers in the pits were 2 to 4 in the different sites of the blocks. The depth of the layers was different in all the pits. The structure, consistence and texture were satisfactory for long-term farming. The tillage operation, crop root growth may be appropriate due to satisfactory structure, consistence and texture. Similarly, abundance of mottles was absent or negligible means drainage status is good and ground water table is far below the excavated depth. This is good symbol for maize growth and development because maize crop cannot tolerate water stagnation. Likewise, the abundance of gravel was also absent or negligible means root growth is satisfactory as well no obstacles for nutrient and water uptake from soil to plants. The soil was acidic in all the layers of pits. The pattern of organic matter, macro and micronutrient as well as sand, silt and clay content was decreasing, increasing and intermittent from surface to bottom layers. A single layer is not dominant for all the physico-chemical properties in all the pits. In overall, upper layer is more fertile than other layers in all the pits.

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AUTHOR CONTRIBUTIONS

D.K. conceptualized and designed the experiment. D.K., S.L., B.R.B. and P.A. studied pit layers in-situ, and collected soil samples for laboratory analysis. D.K. and S.J. analyzed collected soil samples in the Soil Science Division laboratory. D.K. wrote the paper, and final approval of the paper was done by A.P.T., K.S. and B.D. J.

CONFLICTS OF INTEREST

The authors declare that there is no conflicts of interest

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Technical efficiency of certified maize seed in Palpa district, Nepal: A stochastic frontier production approach

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ABSTRACT

The cereal crop, maize is regarded as staple food mainly in hill areas of Nepal. Seed is one of the vital input which determines the production and yield of any crop. Farmers are found using the required inputs in haphazard way which had increased the cost of production and inefficiency of resources used. The study on seed sector is limited. For such a backdrop, this study was aimed to assess the level of technical efficiency (TE) of certified maize seed production. The total of 164 certified seed producer were interviewed in June, 2016 using simple random sampling technique in Palpa district of Nepal. The result revealed that increase in amount of seed and labor by one percent would increase the yield of certified maize seed by 0.29 and 0.34 percent respectively. The TE was estimated using stochastic production frontier model in Stata software. The average TE was found 70 percent which revealed the scope of increasing TE by 30 percent using the existing available resources. There were about 29 percent farmers who had TE of ≥0.7-0.8 followed by 27.44 percent at ≥0.8-0.9. Government and other stakeholders should prioritize to provide technical knowledge via training and increase the visit of extension worker to increase TE of certified maize seed producer in the district.

Keywords: Certified seed, maize, stochastic frontier, technical efficiency

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INTRODUCTION

Nepal is an agrarian country where about 65.6 percent population is directly involved in agriculture for livelihood, income and employment (CBS, 2012). The share of agriculture sector to national Gross Domestic Product (GDP) is about one-third. Maize is grown in 891,583 hectares (ha) with total production of 2,231,517 tonnes (t) which is considered as second most important crop in Nepal (AICC, 2017). Similarly, in Palpa district, it is grown in 20,210 ha having total production of 42,386 t and yield of 2.1 t/ha respectively (CBS, 2016). Nepali agriculture is dominated by smallholder farmers with subsistence farming system. According to the report FAO (2013), the yield of maize (2.5 t/ha) in Nepal is very low as compared to global scenario (5.52 t/ha). Whereas, the increase in maize production is only because of increase in maize area, not due to increase in yield (ABPSD, 2014). The demand of maize is increasing at geometric ratio due to changing food habit and growing feed industry (IFPRI, 2010). The limited supply of quality seed in Nepal (Pullabhotla et al., 2011) has become major limitation on commercial scale production and better yield. Maize has shown better potential in increasing the yield of smallholder farmers with the adoption of new technology (Kibaara, 2005).

Seed is one of the crucial and inexpensive input which has a major role in contributing crop yield (Langyintuo, 2005). Quality and newly released improved seed contains various traits such as earliness, disease resistant and increased yield potential which governs the yield and value of the commodity in the market (Sentimela, 2006). This helps in the improvement of livelihood of rural people as well as helps in poverty reduction.

Seed production demands high management skills and more labor as compared to grain production (Thomison, 2013). There is limited scope to increase the land size, so need to focus on efficiency of inputs used. Technical efficiency is defined as the ability of a unit to obtain maximal output from a given set of inputs (Farell, 1957). The study on TE provides the pathway in order to increase yield by improving efficiency of existing resources (Kibaara, 2005). Introduction of new technologies would not be meaningful unless the existing resources is used to its full potential. Quality seed alone can contribute to 15-20 percent increment in yield (SQCC, 2013). The demand of quality certified seed is high which requires intensive care and management for its production. This study was aimed to estimate TE of certified maize seed producer to know the existing status of resources used and possible remedial measures to increase TE.

METHODOLOGY

Selection of study area

For this study, the highest maize seed producing district, Palpa was selected. The district is located in Province number five at mid-hill area of western development region. The guidance on technical aspects of seed provided by District Agriculture Development Office (DADO) and Nepal Agricultural Research Council (NARC). DADO had been providing fifty percent subsidy on maize source seed to farmer groups and cooperatives. The experience in certified maize seed

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production was about six years in study site. There were no any research regarding the efficiency of seed production in the district despite of its high share in national maize seed production.

Sampling techniques, sample size and data collection

There were eight farmer groups (FGs) and three cooperatives with total population size of 260 farmers involved in seed production. The list of farmers involved in maize seed production was obtained through DADO office, Palpa. The software Raosoft was used to determine the sample size at 95 percent confidence level and margin of error of 4 percent. The recommended sample size was 182 which represent 70 percent to the total population (http://www.raosoft.com/samplesize.html). The total of 182 random numbers were obtained from Microsoft excel using the formula "randbetween". The respective household was selected for the collection of primary data. There were about 10 percent (n=18) and 90 percent (n=164) foundation and certified seed producer respectively. As there were more number of certified seed producers, this study aimed to estimate the TE of certified seed producer. Primary data was collected in the month June, 2016 using face to face interview method using the pretested interview schedule. Total of four FGDs and few KIIs with officers from DADO, president of farmers' group and cooperatives was conducted to triangulate the data collected during field visit.

Stochastic production frontier model

There are various methods to estimate TE. This study used stochastic production frontier model to compute TE as this model explicitly accounts for statistical noise. The required inputs in certified maize seed production are described below. Estimation of TE was based on Coelli, Rao, O'Donnell and Battese (2005).

$$Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}X_5^{b_5}$$

Where,
Y = Yield (kg/ha)
X_1 = Foundation seed sown (kg) in ha
X_2 = FYM used (kg) in ha
X_3 = Chemical fertilizer used (kg) in ha
X_4 = Labor used (man-days) in ha
X_5 = Tillage using tractor (hour) in ha
a = Intercept
b_1....b_5 are the elasticity to be estimated.

The stochastic frontier production model was explained by Aigner, Lovell and Schmidt (1977); Meeusem and van den Broeck (1977) as:

$$\text{Ln } q_i = x_i b + v_i - u_i$$

Here v_i was added to capture the statistical noise which arises due to omission of important variables. This model is stochastic frontier production method[1].

[1] Because output values are bound with stochastic variable $x_i b$ and v_i

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Battese (1992) and Raham (2003) applied the stochastic frontier production method to estimate the TE which is followed in this study. The measure of TE (in terms of output) is shown below:

$$TE_i = \frac{q_i}{\exp(x_i'\beta + v_i)} = \frac{\exp(x_i'\beta + v_i - u_i)}{\exp(x_i'\beta + v_i)} = \exp(-u_i)$$

The value of TE lies in between zero and one. TE is estimated by comparing the yield of maize seed with the yield that can be produced at a full efficient level using the existing inputs or resources.

$Y = f(X_i; b_i) + l$

The error term is composite (Chavas, Petrie and Roth, 2005; Rahman, 2003; Sharma and Leung, 2000).

Thus,

$L= v – u$

Where,

Value of 'v' lies between $-\infty$ and $+\infty$ which accounts the effect that are not under the human control and error due to removal of important variables and measurement. Whereas 'u' which value is positive real number accounts for the measurement of technical inefficiency. Thus TE of certified maize seed producer was estimated by the maximum likelihood method.

RESULTS AND DISCUSSION

Socio-economic and demographic characteristics of certified maize seed producer

The descriptive analysis revealed that in an average, the age of household head (HH) was about 57 year with a schooling of five years formal education. The total owned land (0.91 ha) was found higher as compared to average national landholding size (0.68 ha) and farmers allocated only 0.32 ha for certified maize seed. The household size was found greater as compared with national household size (4.88) and Palpa district's average (4.41). Similarly, there were about 73, 52 and 43 percent male headed household, joint family and migrated members respectively. The access to extension service and participation on training was found better with 90 and 68 percent respectively.

Table 1. Description of socio-economic and demographic characteristics

Variables	Mean (±standard deviation)
Age of HH (year)	56.60±14.36
Year of schooling of HH	5.45±4.65
Household size	5.38±2.67
Total owned land (ha)	0.91±0.80
Area under certified seed production (ha)	0.32±0.17
Participation on training (Yes=1)	111 (67.70)
Access to extension service (Yes=1)	147 (89.60)
Gender of HH (Male=1)	119 (72.60)
Family type (Joint=1)	85 (51.80)
Migration (Yes=1)	70 (42.70)

Notes: Figure in parentheses indicate percent. SD is calculated for continuous variable and percent for categorical variable.

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Estimation of technical efficiency

The statistically highly significant value of wald chi-square (54.77) indicates that the model is strong enough to explain the variations on TE. The explanatory variables such as foundation seed, FYM, labor and tillage were statistically significant at either 1, 5 or 10 percent level of significance. The model showed positive influence of all explanatory variables on yield of certified seed production. The result revealed that increase in amount of seed and labor by one percent increases the yield of certified maize seed significantly by 0.29 and 0.34 percent respectively. Similarly, increase in FYM by one percent increases the yield significantly by 0.04 percent 5 percent level of significance. Also, increase in tillage hour by one percent increases the yield by 0.01 percent and was observed statistically significant at 10 percent level.

The estimation of TE resulted in an average of about 70 percent. The minimum and maximum TE was observed to 24 and 92 percent respectively. This stated the scope of increasing TE by 30 percent using the existing resources in the study site. All the concerned governmental organizations and private sectors should focus to increase TE using the existing resources which helps to reduce the cost of production as well as helps to obtain high return from the certified seed production.

Table 2. Estimation of TE using stochastic production frontier model

Variables	Coefficients	Standard error	z	P>z
Log Seed (kg)	0.286***	0.111	2.58	0.010
Log FYM (kg)	0.038**	0.019	2.07	0.038
Log fertilizer (kg)	0.009	0.008	1.17	0.241
Log Labor (MD)	0.337***	0.082	4.09	0.000
Log Tillage (hr)	0.013*	0.007	1.7	0.088
Constant	4.715***	0.439	10.74	0.000
Sigma v	0.265	0.042		
Sigma u	0.504	0.076		
Sigma^2	0.324	0.062		
Lambda	1.897	0.110		
Observations	164			
Wald Chi2 (5)	54.77			
Prob>Chi2	0.000			
Log likelihood	-81.062			
Mean technical efficiency	0.6996±0.138			
Minimum TE	0.24			
Maximum TE	0.92			

Note: *** , ** and * indicate significant at 1, 5 and 10 percent level of significance respectively.

Oluwatayo, Sekumade and Adesoji (2008) revealed the technical efficiency of 68 percent among maize farmers in rural Nigeria. Chirwa (2007) and Kibaara (2005) found very low technical

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efficiency i.e. 46 and 49 percent among maize farmers and identified the major factor for low efficiency as inappropriate use of fertilizer. Similarly, Abdulai and Eberlin (2001)noted average TE of around 70 percent among maize farmers in Nicaragua using translog stochastic frontier model which was similar to this study.

The technical efficiency scores were categorized in an interval of 10 (figure 1). The majority of the farmers (29.27%) were at TE level of ≥0.7-0.8 followed by 27.44 percent at ≥0.8-0.9, 20.12 percent at ≥0.6-0.7 and so on. The estimation revealed that there were about more than fifty percent farmers having technical efficiency level more than 70 percent.

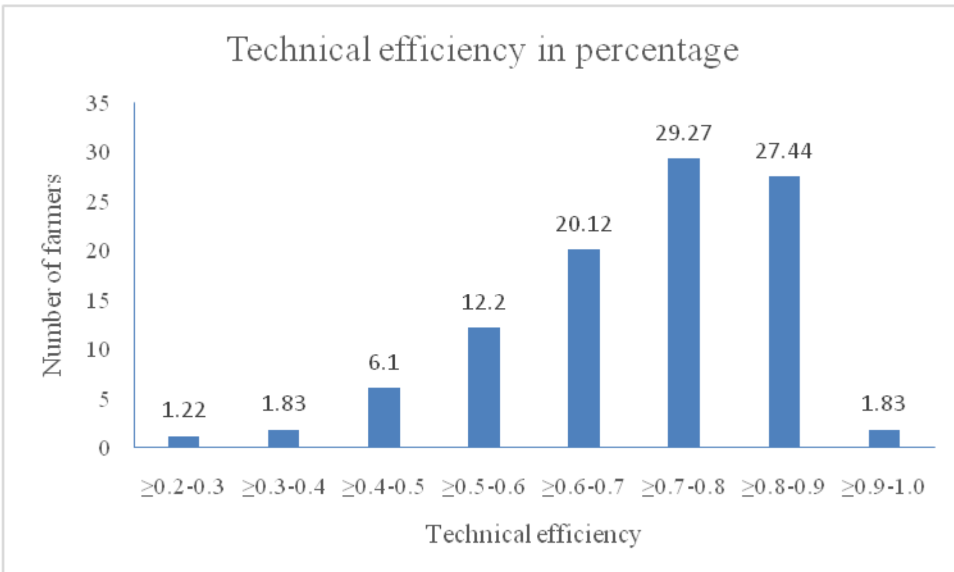

Figure 1: Technical efficiency of certified seed producer

CONCLUSION

The majority of the farmers were at a stage of above 70 percent TE which clarifies that government and other concerned stakeholders should focus to provide technical knowledge on maize seed production and adopt good agriculture practices. Need based training on maize seed production, practice of rouging and frequent visit of extension worker to farmers might help to increase TE. It would be better to deliver programs and activities prioritizing to increase TE rather than discovering new one.

ABBREVIATIONS

DADO: District Agriculture Development Office; **FGD:** Focus Group Discussion; **FYM:** Farm Yard Manure; **ha:** Hectare; **HH: Household head; KII:** Key Informant Interview; **MoAD:** Ministry of Agricultural Development; **t:** tonnes; **NARC:** Nepal Agricultural Research Council; **TE:** Technical efficiency; **VDC:** Village Development Committee

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AUTHORS' CONTRIBUTIONS

M.B. designed whole study procedure, prepared the first draft of this study and reviewed several literatures. Whereas M.S. assisted M.B. in designing the study, collection of field data, analyzed the data, revised the first draft minutely for finalization and drafted the final manuscript to the journal.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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Climate change and maize agriculture among Chepang communities of Nepal: A review

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ABSTRACT

This paper reviews recent literature concerning effects of climate change on agriculture and its agricultural adaptation strategies, climate change impacts on Chepang communities and their maize farming. Climate change is perhaps the most serious environmental threat to agricultural productivity. Change in temperature and precipitation specially has greater influence on crop growth and productivity and most of these effect are found to be adverse. Climate change has been great global threat with global temperature rise by 0.83 °C and global sea level rise by 0.19 m. Poor countries of the world are more vulnerable to changing climate due to different technological, institutional and resource constraints. In context of Nepal, practices like tree plantation, lowering numbers of livestock, shifting to off farm activities, sloping agricultural land technology (SALT) and shifting cultivation are most common coping strategies. Chepang, one of the most backward indigenous ethnic groups of Nepal are also found to perceive change in the climate. Perception and adaptation strategies followed by different farmers of world including Chepang is mainly found to be effected by household head's age, size of farm, family size, assessment to credit, information and extension service, training received and transportation. Maize is second most important crop in Nepal in which increase in temperature is favorable in Mountain and its yield is negatively influenced by increase in summer rain and maximum temperature. Local knowledge of indigenous people provides new insights into the phenomenon that has not yet been scientifically researched. So, government should combine this perceptive with scientific climate scenario and should conduct activities in term of adoption strategies and policies to insist targeted and marginalized farmers.

Keywords: Climate change, maize farmers, coping strategies and Chepang communities.

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INTRODUCTION

The world now faces one of the most complex issues which it has ever had to deal with: climate change. Climate change at present has moved from being hypothesis to being reality and has became a important global threat to all economic sectors, being agriculture a major one. Developing countries like Nepal is more adversely affected by the negative effect of changing climate and rank 9thin Global Climate Risk Index in terms of exposure to various extreme climate (Sönke et al., 2015). Nepal has agrarian economy where agriculture contributes about 33.1% to total GDP (MoAD, 2014). Despite of its significant share to the overall economy, agriculture sector faces serious challenges from changing climate induced impacts like rising temperature, droughts, flood, increasing disease, pests and loss in yield. Agriculture here is the important source of support for the majority of Nepalese households, adapting the agricultural sector mainly for negative effects of climate variability is necessary to assure food security for country and to protect livelihood of Nepalese households. Adaptation to changing climate is an effective tool at the farm level to reduce climatic vulnerability by making Nepalese farmer able to prepare themselves and their farming to changes and variability in climate along with avoiding projected damages and boosting up them in dealing with adverse events (IPCC, 2001).

Chepangs are earliest known inhabitants in Nepal and one of the most backward indigenous nationalities occupying 0.23% of national population. Hills of Chitwan, Makwanpur, Dhadhing and Gorkha are major habitat for Chepang community where 95% of total Chepang are dwelling since long ago. Chepang falls under the highly marginalized category both spatially and socioeconomically. The literacy rate of Chepang community is only 13.9% (CBS, 2003) which hampers their participation in administrative and economic sectors. Chepangs live in the wildest imaginable state of nature and many of them still lead a primitive life. They are well known for shifting cultivation practice which is the main source of livelihood for almost all of them. Agriculture farming is main source of their food but farming alone is not enough to sustain their family food requirements for the whole months in a year. Other traditional occupations are hunting, fishing, and collecting edible shoots and roots, wage laboring and salary job are also done for cash income. Like other part of world Chepang people are also facing various changes in climate and are formulating their own adoption strategies for to prevent fluctuation in their agricultural production. Adoption strategies like changing planting time, using drought and heat resistant variety, adoption of agro forestry, development of water conservation techniques and diversification of off farm activities are very common among Chepang communities.

Maize is second most important crop on Nepal which is cultivated in 2145291 hectare area. Its total production is about 882395 metric tons. Its average productivity is 2400 kilograms per hectare. The Hill area that extended from east to west is the most important maize growing area. Eastern, Central and Western Hill are the highest maize growing areas of the country. Chitwan district ranks first in maize production where as Kavre and Tanahun districts rank second and third position respectively. Productivity of maize is found to be highest at Kathmandu. Like as other crops maize is also influenced by climatic change and most effects have negative impact on yield and productivity. Different adoption strategies have been adopted at local level and its

more explanation and exploration can be a best strategy for to increase economic importance from maize at present context.

Although various study has already been done about climate change but very few studies can be found regarding perception of indigenous community like Chepang community towards climate change. So this study tries to focus on indigenous farmers indicating what perception they have to the impact of climate change on agricultural production, different problem they have faced and how they cope with these changes. Furthermore it will also highlight on factors that influence on farmers choice of adaptation strategies and what is the effect of such strategies on farmer's crop production and food security. Moreover this finding will also be fruitful for policy makers and stakeholders who are concerned in agricultural development, poverty alleviation, food security as well as the disaster management. The overall objective of this review is to gather knowledge about climate change and agriculture along with different mitigation measure adopted at different part of world including adoption strategies followed by Chepang community.

DISCUSSION

Climate change and its effect on agriculture

IPCC, Intergovernmental Panel on Climate Change has defined climate change as any types of changes that occurs on climate over time which arises as a result of both human activity and natural variability where as UNFCC (United Nations Framework Convention on Climate Change) defines climate change as a change in climate that is contributed directly or indirectly to human activity that influence the composition of global atmosphere.

The Food and Agriculture Organization (FAO) states that considerable efforts need to be done to prepare developing countries to deal with climate-related effects, especially in agriculture (FAO, 2007).Through the recent study IPCC noted that there are viable adaptation options that can be implemented at low cost along with high benefit-cost ratios (IPCC, 2007).

IPCC in its fifth assessment report has stated that the anthropological emission of green house gases are increasing day by day and has became the highest in history at the present condition which has various impacts on human and natural system. Due to these gases atmosphere is warming, snow is malting and sea level is rising. The global temperature has risen by 0.85°C (0.65-1.06 °C) from year of 1880 to 2012 where as global sea level has raised by 0.19m (0.17-0.21m) over a period of 1901 to 2010 .The increase in global mean temperature at the end of twenty first century (2081-2100) compare to 1985-2005 is expected to be in between 0.3°C to 4.8 °C and seal level is expected to rise between 0.26- 0.82m in the same period of time. Also, change in precipitation is expected to be irregular with increase in mean annual rainfall in high altitude and decrease in mean annual rainfall in mid altitude dry reason. Anthropogenic gases emission in atmosphere has increase the concentration of carbon dioxide, methane and nitrous oxide. Among total anthropogenic carbon dioxide emitted 40% remains in atmosphere where as 30 % is absorbed by ocean leading to ocean acidification and rest is absorbed by land causing various bad effects (IPCC, 2014).

Developing countries like Nepal contribute very less to global green house emission but these are the one most affected by the effect of climate change. Nepal contributes 0.025 percentage to green house emission but is ranked 4th on Maplecorft's climate vulnerability index (Maolecorft,

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2011).Nepal is experiencing increase in temperature, erratic rainfall, irregular onset of monsoon which has increased the vulnerability of glacier lake outburst, drought, landslide and flood. Temperature of the country is increasing gradually (Shrestha et al., 2000; Ebi et al., 2007). While the precipitation has been more erratic, heavy and unpredictable with more droughts and shorter periods of winter rainfall (Shrestha et al., 2000). Annually precipitation of Nepal is increasing by 13mm and days of rainfall are decreasing by 0.8 days per year (Manandhar et al., 2011). Flood at Koshi river at eastern Nepal in 2008 and flood at west Rapti at western Nepal in 2012 is a good example of devastating flood in Nepal (Sinha et al., 2008). Mainly western part of Nepal around west Rapti river basin is experiencing more than expected flood resulting heavy damage in human lives, their properties and serious losses in agricultural production every year (Marahatta et al., 2009) .In case of mountains of Nepal for over thirty years snow covers has been reduced, glacial area has been depleted by about 21 % and here tree line has been shifted to higher altitude (Synnott, 2012) where as in hill there has been change in intensity and timing of rainfall along with high incidence of pest. Lastly in terai, incidence of flood has been increased due to melting of snow and different glaciers outburst (Blunden et al., 2012).In context of Chitwan monsoon rainfall varies from year to year and is decreasing in trends in long term basis where as whereas summer and winter temperature increasing over a period of time (Pandey & Neupane, 2017) .

Climate change seems to have more impacts on large animals then in smaller ones. At the current situation climate change has been considered as an additional factor which along with other conventional pressures can have a significant effect on the scale, form and temporal and spatial effect on agricultural production. In the absence of proper strategies to long lasting climate change and climatic variability, different diverse and region-specific impacts will become more prominent and apparent. Most of the impacts of climate change are found to have negative effect on agriculture where as others are found to be favorable. Climate change has potential to influence crop and livestock production, input supplies, hydrological balance and other components of agriculture system. It can also change frequencies, intensities and type of various crops and livestock pests, severity of soil erosion, availability and timing of irrigation water supplies and also affects demand of labor, energy and equipments (Adams et al., 1998). It is very important to consider agriculture sector in term of climate change as it get affected by changing climate as well as contributes to climate change (Aydinalp & Cresser, 2008). Due to various factors effects of climate change on the agricultural sector have increased its concern over the magnitude of future global food production (IPCC, 1996).

Different component of climate like temperature, solar radiation, rainfall, wind velocity and relative humidity in combination or individually may influence crop growth and productivity (Ghimire, 2008)**.**In higher and middle altitude higher temperature will lengthen season of growing along with extending area of crop production pole ward where as at the lower latitude higher temperature will inversely affect the growing condition especially in areas where temperature are close to optimal temperature required for the growth of crop. Change in temperature and precipitation affects irrigation availability and demand. Increase in temperature causes increase in potential evapo transpiration which will intensify stress due to drought especially in tropics, subtropics and semi arid (Rosenzweig & Hillel, 1995). Based on agronomic research in countries of lower latitude approximate global welfare changes in the agricultural sector (without adaptations) has losses of US$61.2 billion and gains of US$0.1 billion which is

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in contrast with the losses of US$37 billion to gains of US$70 billion with appropriate adaptations in same place (Reilly, et al., 1996).

In Africa and South and East Asia decline in aggregate production is anticipated which showed that in Asia rice production may decline by 3.8 percent of production level under likely future climate regimes. In addition it is also accepted that negative effect of climate change in agriculture will increase the severity of incidence of poverty in rural areas (Murdiyarso, 2000).

In addition to crops climatic change also have various impacts on livestock. Different indirect impacts like reduction in forage and grass productivity, decrease in productivity of crops used as feed for poultry and live stocks, increase in water shortage and increase in distribution and severity of human livestock and crop disease (Hahn et al.,1992) where as direct impacts in livestocks due to climate change includes reduction in milk production and conception rate in dairy animals during summer season (Klinedinst et al., 1993)

Agricultural adaptation strategies to climate change impacts

Adaptation to climate impacts in general condition and in the sector of agricultural sector has been well introduced phenomenon. Different natural and socioeconomic systems have continuously been adapting autonomously where as in some places adaptation is in accordance with a plan of changing environment (Rosenberg, 1992).Adoption strategies for climate change in agriculture are mainly of two types – short term adaptation strategies and long term adaptation strategies.

Short term adaptation strategies include activities like improve nutrient management, diversification in crop and livestock and variation in time of farm operation, temporary migration, crop and livestock insurance etc. Contouring, terracing, construction of divisions and water storage can reduce the effects of climate change by reducing soil erosion, runoff and promoting nutrient storing capacity of soil (Easterling, 1996; Gylling & Abildtrup, 2001). Along with increase in temperature and change of climate, outbreak of different disease and pests become very common. This can be reduced by appropriate application of proper pesticides and adopting proper integrated insect and pest management techniques (Downing et al., 1997). Agro forestry can be a useful climate change adaptation strategy. In 2002 Adesina and Chianu enlighten that in case of Nigeria ,adaptation to agro-forestry as a tool for coping climate change vulnerability was significantly found to be effected by gender of farmer, experience of agro-forestry , contact with extension agents, fuel wood pressure, land pressure ,distance from urban area and importance given for livestocks as economic activities. Meanwhile human capital variables were found to be significant for taking decisions regarding adaptation and modification of required technology. Moreover, changing the sowing time, planting, spraying, adjusting the cropping sequence and harvesting can be used to take advantage of the changing duration of growing seasons and associated heat and moisture levels (Brklacich et al., 2000). IPCC (2001) has discussed insurance which may be informal and formal as well as public and private as a potential measure to reduce negative losses that arises from climate related impacts.

Long term adaptation strategies include – changing crop types and location, water management, developing new technology and modernization, permanent migration etc. One of the best options for climate change is to switch to more robust varieties which show better result in new environment. Matarira and Mwamuka (1996) reported that in Zimbabwe farmer has successfully switched to use more drought tolerant crops where drought has made difficult to use traditional

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crop varieties. In extreme cases farmers have converted agricultural land into game ranching. Similarly watershed and landscape management, law and regulation, use of economic instruments, efficient and effective weather forecasting system, flood risk management system, rising awareness and data bases related to flood can also be used to mitigate vulnerabilities of climate change (Kundzewicz, 2002). Proper water management technique can also reduce effects of climate change. Bullock and others (1996) state that when there is short supply of water advance irrigation practices like underground irrigation and drip irrigation can be used which helps in water conservation up to 50 percent in comparison to conventional ones.

In high Himalayan region of Nepal adaptation strategies for climate change were found to be very limited. Farmers in this region stated that due to the decline in grass land and grass production they are lowering their livestock numbers and had practiced rotational grazing where as shifting cultivation by farmers and engaging in hotel business or migrating to other places were also found to be common. Likewise farmers in Siwalik and mountain have been managing community forests, water harvesting and adopting Sloping Agriculture Land Technology as an agro-forestry (Herto-Silviculture) practices in their steep land to lower soil erosion and Chepang in Siwalik are minimizing their shifting cultivation. Moreover, majority of farmers were also found to be busy in practicing vegetable production rather than cereal production. Lastly, in terai farmers are developing community forest and planting trees in their private lands. They have adopted irrigation cannels and pumps for to meet water requirement of their field and have done river training and embankment in order to protect their agricultural field. In addition they have also adopted use of high yielding variety, chemical fertilizers, insecticides and pesticides (Tiwari et al., 2010).

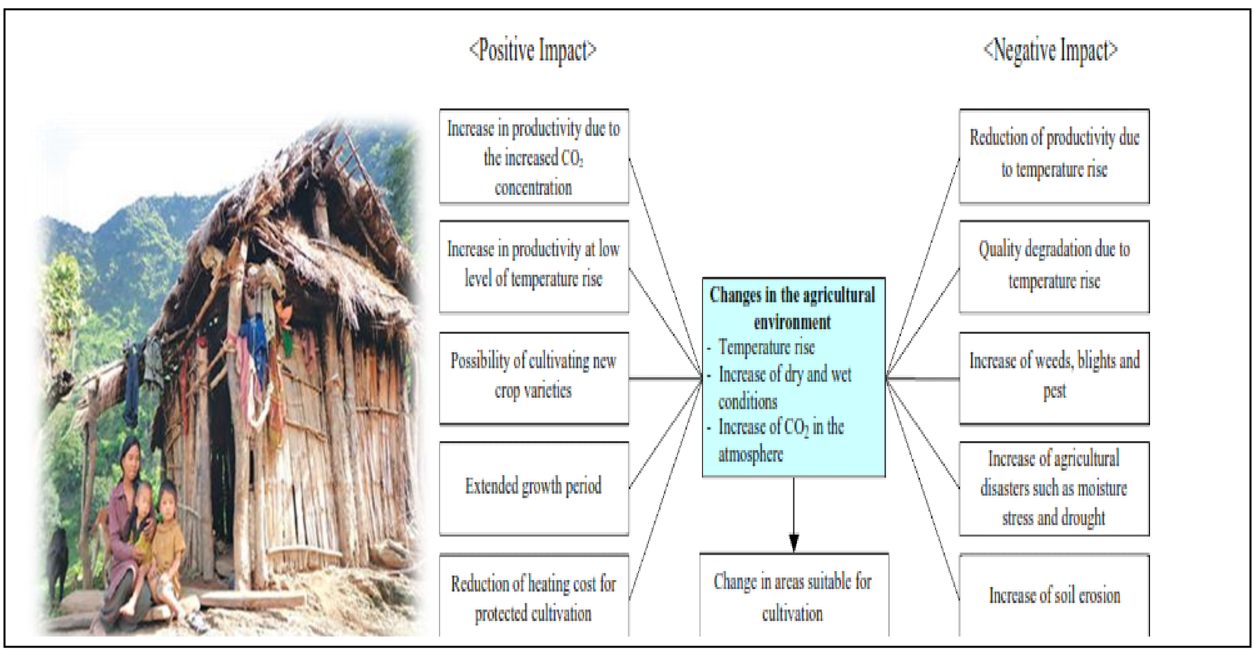

Figure 1: Potential impacts of global warming on the agricultural sector and farmers' livelihood (Source: adopted by Chang-Gil, et al. 2009).

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In context of Ethiopia change in varieties of crops, water and soil conservation, tree planting, early and late planting and harvesting, and irrigation were major adoption strategies for climate change (Temesgen et al., 2009).

In Bangladesh farmers were found to adopt fourteen adoptation strategies for to mitigate adverse effects of climate change which were-increased irrigation, integrated farming system, crop diversification, use of salinity tolerant varieties, use of drought tolerant varieties, crop rotation, cultivating short duration crops, practicing intercropping, engage in off-farm job, moved to non-farm activities, agro forestry, soil conservations techniques, zero tillage and crop insurance. Amoung these different adoptation irrigation rank first and crop insurance rank last (Mohammed et al., 2014).

Factors affecting adoption of climate change adaptation strategies

Along with the experience of climate change farmers are adopting different strategies to deal with its adverse effects but these strategies are found to be effected by different determinant. Climate change adaptation strategies adopted by farmers are found to be effected by accurate and frequent climatic information from meteorological centre, credit assessment and information about extension, involve in formal and informal institutions, rainfall amount, geographical location, age ,size of household and education status of household head (Yesuf et al., 2008). Assessment of electricity and other technology, land ownership, market facilities and gender of household head found to have significant influence on household choice in adaptation to climate change (Nhemachena & Hassan, 2007) while poverty, lack of well secure property rights, poor savings, size of farm, poor technical skills and non-farm employment acts as additional barriers to adoption of different strategies for climate change. Similarly livestock ownership, amount of precipitation and local temperatures also helps in determining the household's choice while adapting strategies to climate change (Yesuf et al., 2008) .

A research done at Chepang community showed that conventional adaptation strategies to climate change are found to be influenced by landholding size, land tenure status, perception about climate change, credit assessment, extension and information service, training related to skill development and access of transportation service which enables farmers to adopt new practices to cope climate vagaries (Piya et al., 2013). In Bangladesh age, education, size of family, farm size, income of family and involvement in cooperatives were significant factors for self reported adoption strategies. In this case it has been found that age, farm size and family size were found to have significant negative effect where as education, farm income and involvement in cooperatives were found to have significant positive impact. Lack of availability of water, shortage of land for cultivation, and unpredictable weather are ranked as highest constraints for respondent group to tackle with environmental change effect and degradation (Mohammed et al, 2014).

Adoption choices of farmer's of Nile river basin of Ethiopia are influenced by gender, education, age, and wealth of the head of household, assessment to credit and extension, climatic information, agro ecological settings, social capital and temperature where as major barrier were poor information on adaptation methods and financial constraints (Temesgen et al., 2009). In the same way adoption in Swaziland is significantly affected by household head's age, membership in social group, category of land, availability of credit, assessment to extension service and training, incidence of pest and disease, high price of inputs and food. In contrast

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education and sex status of head of household is insignificant to adoption to climate change (Shongwe et al., 2014). Charles and Rashid (2007) identified that assessment to credit and extension and climate change awareness are some of the important determining factor for adaptation at farm level in South Africa, Zambia and Zimbabwe.

Figure 2: Different dimensions of adaptation (Source: Peterson & Stafford, 2009)

Climate change impacts on Chepang community

Vulnerability of climate change is increasing day by day is highly threatening human livelihood. In comparison to urban, rural communities especially of developing countries are expected to affect more because of their extensive dependence on climate sensitive options and limited adoptive strategies to the changes (UNFCCC, 2009). Local community study local climate closely and adopt different strategies .These incorporating indigenous knowledge could play significant role in mitigating increasing risk of changing climate (Nyong et al., 2007) Chepang are marginalized indigenous ethnic groups of dwelling at rural mid hills of Nepal and are highly vulnerable to climatic changes. One third of the Chepang farmers under study were found to perceive change in climate. Most commonly observed climatic hazards in Chepang community are landslides, drought and hailstones. In these community drought has been more frequent. Short duration droughts followed by uncertain rainfall have highly hampered maize cultivation. Hailstone is also occurring more frequently mainly during April to May and has effect crops like maize, orange and pear. In major dwelling areas of Chepang there is late unset of winter rain which mainly lead to late sowing of maize and delay in millet transplantation (Piya et al., 2012)

A survey from Chepang community of Chitwan revealed that 95 percent of local people surveyed perceived changes in temperature where majority of them noticed increase in temperature and few perceive decrease in it. In addition unpredictable rainfall was also observed by them where as only two percent farmers noticed predictable and constant rainfall. Increase in drought, hail storm abnormality, decrease in water sources, change in flowering and fruiting time , disappearance of some indigenous plant and invasion of new weeds are different effect seen by Chepang of Chitwan district of Nepal as a result of climate change (Thapa & Shah, 2010). In another research done in Chepang community of Siddhi and Shaktikhor showed that, 50 percent of the respondents perceived increase in summer temperature, 20 percent perceived a decrease in summer temperature, 6 percent perceived neither increase nor decrease and 24 percent of respondents were not aware about change in summer temperature pattern. 39 percent of

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respondents perceived increasing in winter temperature, 37 percent perceived decrease in winter temperature, 3 percent perceived neither increase nor decrease and 21 percent of respondents were not aware about change in winter temperature pattern. Similarly 58 percent perceived decrease in rainfall amount as compared to past while 57 percent respondent perceived decrease in duration of rainfall. 49 percent respondents perceived that rainfall time is unpredictable (Pandey & Neupane, 2017) .Perception of temperature and rainfall change is mostly effected by access to information and extension service. Similarly perception of rainfall is also significantly affected by the cultivation of cash crops where as engagement in off farm income sources and formal education reduce the ability of local farmers to perceive changes in climate (Piya et al., 2012) . Most common climate change copping strategies by Chepang are varietal selection, adjustment in time of sowing ,different soil conservation practices, wild eadible collection, nonfarm job, wage laboring, rearing livestocks, cash crops, water pond construction and depending upon community for assistance (Piya et al., 2013) where as another study showed that forest plantation, crop diversification, marginal land utilization by planting millet, grasses and trees are most common adoption practices of Chepang farmers (Thapa & Shah, 2010)

The conventional adaptation strategies to climate change followed by Chepang community are influenced by landholding size, land tenure status, perception of climate change, access to information, productive credit and extension service, skill development training and access of transportation service which enables farmers to adopt new practices to cope climate vagaries (Piya et al., 2013)

As climate change is all throgh the world peoples in each sectors are using their own strategies to tackel with these changes.In Ethiopia people are using varieties of crops, water and soil conservation, tree planting, early and late planting and harvesting and irrigation were major adoption strategies and gender, education, age, and wealth of the head of household, assessment to credit and extension, climatic information, agro ecological settings, social capital and temperature are influencing factor for their choices (Temesgen et al., 2009) .Similarly in case of increased irrigation, integrated farming system, crop diversification, use of salinity tolerant varieties, use of drought tolerant varieties, crop rotation, etc are major practices where age, education, family size, farm size, family income are significantly related to these adoption practices where education, age, size of family, size of farm and family income are significantly related to adoption practices (Mohammed et al., 2014). in Swaziland is significantly affected by household head's age, membership in social group, category of land, availability of credit, assessment to extension service and training, incidence of pest and disease, high price of inputs and food. In contrast education and sex status of head of household is insignificant to adoption to climate change In Swaziland farmers has adopted varieties resistant to drought, irrigation, switching of crops, crop rotation, early planting, late planting, mulching, intercropping and minimum tillage. These practices are found to be significantly affected by household head's age, membership in social group, category of land, availability of credit, assessment to extension service and training, incidence of pest and disease, high price of inputs and food (Shongwe et al., 2014).

All these shows that as per the intensity and vulnerability of climate change people are adopting their own strategies. As compare to others adoption followed by Chepang are more traditional, old and primitive types. Study showed that there is very less information available about Chepang, their perception and adoptation. So priority placement must be done for the

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dissemination of relevant information from community level and regular updating educational curriculum by including issues related to climate change need to be done .In addition local hyrological station need to established and proper community training need to be done for local people in order to generate local climate based data and to facilate awareness and adaptation in local level.

Climate change impacts on maize farming

Maize is second major crop of Nepal and is considered as a major crop in Hills. Date of sowing is determined mainly by soil moisture availability. As maize is C4 photosynthetic pathway crop, it has less response to atmospheric change in carbon dioxide level. Maize production was increased by 9% in terai, 4.9% in hill and 14.5 % in mountain where as yield decrease by 26.4% in terai and 9.3 % in hill but found to be increased by 26.8 in mountain at 4°C rises in temperature. This showed rose in temperature is favorable for growing maize in mountain in comparison to terai and hills (Nayava and Gurung, 2010).Research has shown that, in context of Nepal, rise in summer rainfall and maximum temperature negatively affect yield of maize. It has suppressed yield of maize by 106 kg/ha (Joshi et al., 2011).

Climate is changing although the world, including the major maize-growing state of Iowa in the USA. In Iowa to maintain crop yields, farmers need adopt different adaptation strategies. Choice of their strategy will depend on how regional and local climate in particular area is expected to change. Maize yields from late 20th century to middle and late 21st century is predicted to range from 15% to 50%. Similarly for each 1°C rise in air temperature in warm season 6% state-averaged yield reduction is predicted. Research results suggested that even if maize receive all its water requirement under strong climate force scenario yields will decrease by 10–20% by the end of the 21st century(Xu et al., 2016). Overall reduction of in maize production up to 2055 is expected to be 10 % whose loss will be equivalent to $2 billion per year. Climate change needs to be assessed household level, so that research and development activities can target poor and vulnerable people depending on agriculture with the objective of alleviation of poverty (Chang et al., 2014).

Finding from research done on China show that climate change has a adverse effect on Chinese agriculture and has caused high flexibility in the timing of maize production and in southwest region a better adaptation to climate change in regional level can help to offset or even to outweigh potential reduction in production of maize in the Northeast region. Research suggest proper inter-regional cooperation, contracts and policies need to be made for the stabilization of agricultural labor force at regional level as a cost-efficient risk mitigation strategy to decrease overall maize production of nation (Li et al., 2014). From the study done on sub humid and semi arid areas of Tanzania indicated that household size and education of the household head positively impacted net farm return from maize production. It also predicted that net revenue obtained from maize production will be negatively affected. Therefore investing in new technologies and adequate extension information services are recommended so as to increase farmer's adaptive capacity to reduce inverse effect of changing climate in maize yield and production (Valarian, 2015).

Maize yield could reduce averagely by 13.2–19.1% without adaptation and 15.6–21.8% could be reduced due to evapotranspiration during growing period at 2050s in comparison to 1961–1990. In relation with the experiment done using high-temperature sensitive varieties without adaptation, adopting adaptation of late planting, variety growing duration fixation and early

planting can averagely increase maize production by 4.1–5.6% , 9.9–15.2% and 1.0–6.0% respectively. Evapotranspiration is estimated to increase averagely by 1.9–4.4%, 1.9–3.7%, and −2.9% to −0.7%, respectively where as by using maize varieties tolerant to high temperature yield could be increase by −2.4% to −1.4%, 34.7–45.6%, and 5.7–6.1%, respectively. The research showed that larger benefits can be obtained by the development of high temperature tolerant crop varieties with high thermal requirements (Tao & Zhang, 2010).

CONCLUSION

Along with the changing climate people from all through the world are adopting different strategies to neutralize its negative effects. These strategies are found to be effected by different facts among them some are found to have positive where as some found to have negative impacts. Local knowledge of indigenous people including Chepang provides new insights into the phenomenon that has not yet been scientifically researched. So, the government should combine this perceptive with scientific climate scenario and should conduct various activities in term of adoption strategies and policies to insist targeted and marginalized farmers. Moreover, strategies to increase yield of major crops like maize need to be focused to reduce hunger and poverty.

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AUTHOR CONTRIBUTIONS

R.R.T gave the concept, provided regular guidelines and revised the article for final approval of the version to be published. P.S. and A.P.S. reviewed various articles and wrote the paper.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Evaluation of early maize genotypes for grain yield and agromorphological traits

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ABSTRACT

The purpose of this study was to assess the variation on agro-morphological traits and grain yield. A set of 14 early maize genotypes were studied at research field of Regional Agricultural Research Station (RARS), Doti, Nepal in summer seasons of 2015 and 2016. The experiment was carried out in Randomized Complete Block Design (RCBD) with three replications in each year. The variation among genotypes was observed for grain yield and flowering. The genotype SO3TEY-PO-BM produced the highest grain yield (4.33 t/ha) in 2015 whereas Rajahar Local Variety produced the highest grain yield (2.52 t/ha) in 2016. The combined analysis over years showed that Farmer's variety was found earlier in tasseling (36 days) and silking (39 days), followed by S97TEYGHAYB(3) in tasseling (45 days) and by S97TEYGHAYB(3) and Arun-4 in silking (48 days). EEYC1 produced the highest grain yield (3.17 t/ha), followed by COMPOL-NIBP (3.09 t/ha), SO3TEY-PO-BM (2.90 t/ha), S97TEYGHAYB(3) (2.78 t/ha) and Rajahar Local variety (2.77 t/ha), respectively. The information on variation for the agro-morphological traits among studied early maize genotypes will be helpful to plant breeders in constructing their breeding materials and implementing selection strategies.

Keywords: Early maize genotypes, grain yield, agromorphological traits.

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INTRODUCTION

Maize (*Zea mays* L.) ranks the second to rice in important cereal crop in Nepal. It is used as food, feed, fodder and raw materials for industries. It is cultivated in 891,583 hectares of land (MoAD, 2017). The production of maize in the country is 2,231,517 t with the productivity of 2.5 t/ha (MoAD, 2017). It is the major food crop in the hills of Nepal (Upadhyay et al., 2009), and accounts about 71% of maize production of the country (MoAD, 2017). Furthermore, the share of cereal crops to AGDP is about 49%, and maize alone contributes about 7% to AGDP (MoAD, 2015). It is a traditional crop and is mostly grown in the sloping *bari* land (rainfed upland) in the hills. Maize cultivation is a lifestyle for majority of the farmers in the hilly region of Nepal (Adhikari, 2000). It is cultivated in a very diverse environment in Nepal (NPC, 1994). Hills and mountain districts of far western development region are characterized by remote, inaccessible, food deficit and drought prone areas of the country. Like other crops, maize productivity in far-western development region is also low (2.0 t/ha) with respect to national average (MoAD, 2017). In many developing countries, several biotic and abiotic stresses are underpinning to confine the maize yield (Prasana, 2012). Further, the adoption rate of improved maize genotypes is 30% lower than eastern and western mid-hills (Gurung, 1999). It might be due to longer duration of improved maize genotypes which could not fit in the cropping pattern. Moreover, early maturing genotypes, which better fit in existing cropping system, are preferred by hilly farmers of far-western development region. Lack of high yielding genotypes suitable for agro-climatic condition, inadequate variety in the existing system, lack of improved seeds and lack of agricultural inputs like irrigation, fertilizers etc. have always been associated with low productivity of maize in far-western development region. Up to now, there are limited options for the high yielding early maize genotypes for the farmers which could fit in the different cropping patterns (Kunwar et al., 2014). Thus, the improved maize genotypes, with high yielding and early maturing that better fit in existing cropping system, could increase and stabilize maize yield in this food deficit region. Therefore, this study was done to identify high yielding and early maturing maize genotypes, which can be cultivated in Far-Western Development Region of Nepal.

MATERIALS AND METHODS

Description of experimental site

In coordination with National Maize Research Program (NMRP), Rampur, Chitwan, a field experiment as Coordinated Varietal Trial (CVT) of early maize genotypes were tested for two consecutive maize growing seasons i.e. 2015 and 2016 summer at research field of Regional Agricultural Research Station (RARS), Doti (610 masl). RARS, Doti is situated at 29°15' north latitude and 85°55' east longitude. It represents the river basin agro-environment of far-western hills (RARS, 2012). The soil of the experiment plots was light texture sandy loam, slightly acidic (pH 5.5-6), low in organic matter content (1-2%), nitrogen is only 0.6% (RARS, 2016). The average annual rainfall received by experimental site is about 1000 mm and generally doesn't exceed it (RARS, 2016).

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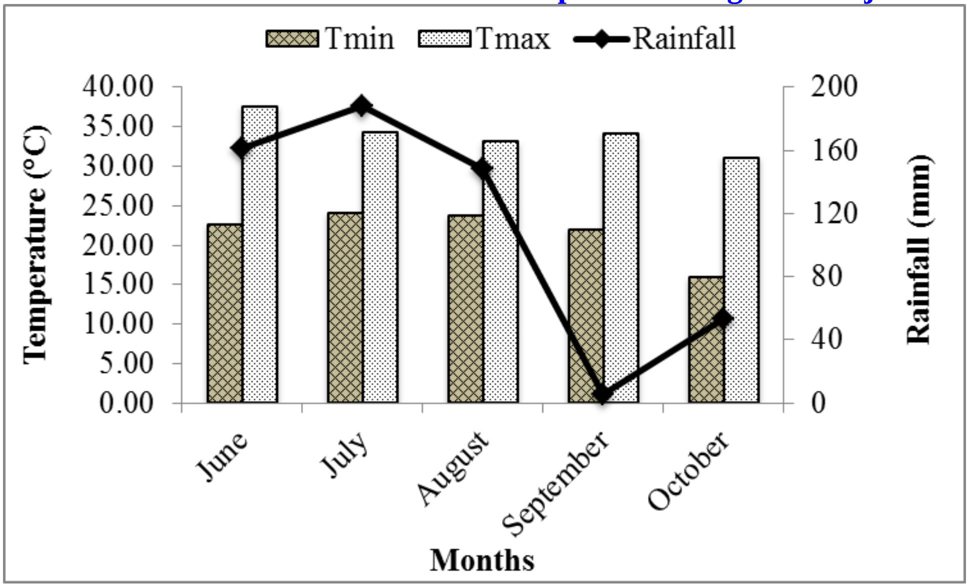

Figure 1: Weather data of experimental site at RARS, Doti during 2015 growing season

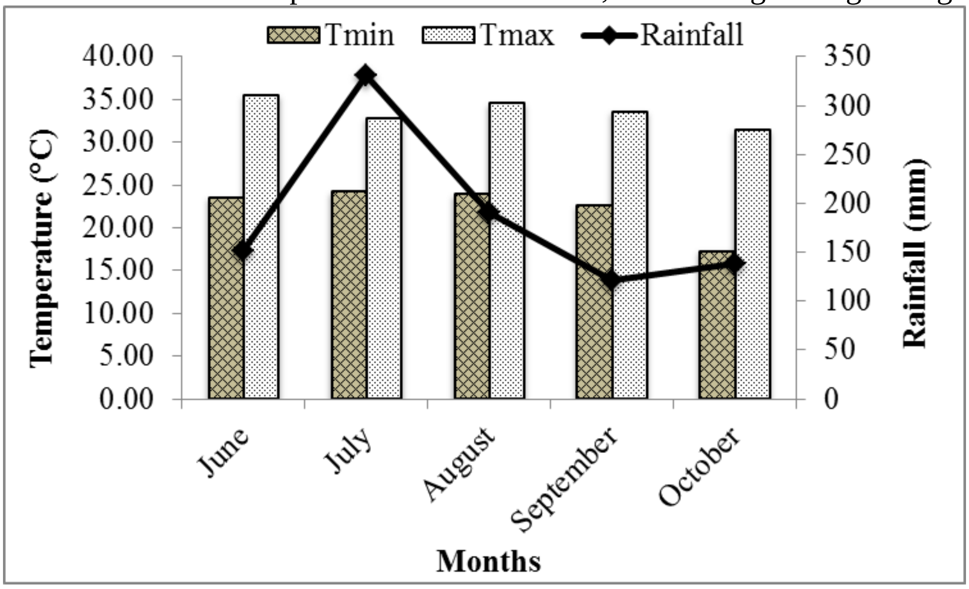

Figure 2: Weather data of experimental site at RARS, Doti during 2016 growing season

Genotypes

The experiment was carried out with fourteen different early maize genotypes in both years. The genotype were: Earlymid Katamani, Rajahar Local Variety, S97TEYGHAYB(3), POP-445/POP-446, COMPOL-NIBP, RC/POOL-17, S03TEY/LM, Arun-4, Farmers' Variety, ZM621/POOL-15, EEYC1, SO3TEY-LN/PP, SO3TEY-PO-BM and Across-99402. Among fourteen genotypes, two genotypes were check genotypes viz. Farmer's Variety as local check and Arun-4 as standard check.

Experimental design and cultural practices

The experiment was carried out in Randomized Complete Block Design (RCBD) and replicated thrice in each year. Maize genotypes and protocols were followed as provided by NMRP, Rampur, Chitwan. The trial was planted on 2nd week of June in each year. In addition

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to 10 FYM t/ha, chemical fertilizers were applied at the rate of 60:60:40 N P_2O_5 K_2O kg/ha during final land preparation. Remaining 60 kg N/ha was top dressed in two splits, i.e. 30 kg N/ha at knee high stage and 30 kg N/ha at tasseling stage. The plot size was maintained by 3m × 3m (4 rows of 3m long) and yield and other data were taken from middle 2 rows. The crop geometry was maintained as 75 cm × 25 cm and two seeds per hill were sown. Thinning was done to maintain plant population after 3 weeks of germination. Furadan 3% was applied @ 3-4 granules/plant to control stem borer.

Field measurements

Plant height, ear height, days to tasseling and silking, number of plants per hectare, number of ears per hectare and grain yield were recorded. Grain yield (kg/ha) was adjusted at 15% moisture content with the help of the below formula:

$$\text{Grain yield }\left(\frac{\text{kg}}{\text{ha}}\right) = \frac{\text{F.W.}\left(\frac{\text{kg}}{\text{plot}}\right) \times (100 - \text{HMP}) \times \text{S} \times 10000}{(100 - \text{DMP}) \times \text{NPA}}$$

Where,

F.W. = Fresh weight of ear in kg per plot at harvest
HMP = Grain moisture percentage at harvest
DMP = Desired moisture percentage, i.e. 15%
NPA = Net harvest plot area, m^2
S = Shelling coefficient, i.e. 0.8

This formula was also adopted by Carangal et al. (1971) and Shrestha et al. (2015) to adjust the grain yield (kg/ha) at 15% moisture content. This adjusted grain yield (kg/ha) was again converted to grain yield (t/ha).

Statistical analysis

A computer software, MSTATC version 1.3 (Freed, 1994), was used for statistical analysis of datas, applying 5% level of significance.

RESULTS AND DISCUSSION

Plant and ear height

Plant height and ear height were significantly influenced by genotypes during both growing seasons (Table 1). During 2015 growing season, Rajahar Local Variety was the tallest genotype in plant height (287 cm) and ear height (126 cm). Farmers' variety and S97TEYGHAYB(3) were identified as dwarf genotypes for plant height and ear height. Prasai et al. (2014), Prasai et al. (2015), Adhikari et al. (2016) also found the genotypic differences in plant height and ear height among the tested genotypes. Similarly, during 2016 growing season, Rajahar Local Variety was the tallest genotype in plant height (250 cm) and ear height (147 cm). POP-445/POP-446 and COMPOL-NIBP were identified as dwarf genotypes for plant height and ear height. Combine analysis over years revealed that Rajahar Local Variety was the tallest genotype in plant height (269 cm) and ear height (137 cm), whereas Farmers' variety (190 cm) and POP-445/POP-446 (196 cm) were identified as dwarf

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genotypes for plant height. Genotypes POP-445/POP-446 and COMPOL-NIBP were identified as dwarf genotypes for ear height. Prasai et al. (2014), Kunwar et al. (2014) and Prasai et al. (2015) also concluded the similar findings in their experiments. The mean plant height of 2016 growing season was shorter than 2015 growing season. It is highly possible that continuous rain for about 3 weeks after maize seeding might have affected the plant growth. Zaidi et al. (2004) also supported that the excessive moisture stress during early vegetative stage severely affects the growth. The detail of data on plant height and ear height is presented in Table 1.

Table 1: Plant height and ear height of early maize genotypes evaluated at RARS, Doti during summer seasons of 2015 and 2016

SN	Genotype	Plant height (cm)			Ear height (cm)		
		2015	2016	Combined	2015	2016	Combined
1	Earlymid Katamani	250	214	232	100	115	108
2	Rajahar Local Variety	287	250	269	126	147	137
3	S97TEYGHAYB(3)	211	240	225	75	127	101
4	POP-445/POP-446	222	169	196	78	65	72
5	COMPOL-NIBP	232	178	205	77	87	82
6	RC/POOL-17	251	211	231	111	112	111
7	S03TEY/LM	256	232	244	107	100	103
8	Arun-4	245	232	238	106	125	116
9	Farmers' Variety	195	184	190	75	91	83
10	ZM621/POOL-15	241	199	220	97	93	95
11	EEYC1	271	221	246	101	113	107
12	SO3TEY-LN/PP	253	207	230	96	106	101
13	SO3TEY-PO-BM	273	203	238	102	99	100
14	Across-99402	233	204	219	90	103	96
	Mean	244	210	227	96	106	101
	F test						
	Genotypes (G)	**	**	**	**	**	**
	Year (Y)			**			**
	G × Y			*			ns
	LSD $_{(0.05)}$						
	Genotypes (G)	20.48	37.49	22.140	22.90	30.41	19.560
	Year (Y)			8.370			7.390
	G × Y			31.320			
	CV (%)	5.0	10.6	8.4	14.2	17.1	16.8

(Note: ns = non-significant at 5% level of significance, *=Significant at 5% level of significance, **= significant at 1% level of significance)

Days to tasseling and silking

During 2015 growing season, both days to tasseling and days to silking were significantly influenced by genotypes. Genotype farmers' variety was early in both tasseling (37 days) and silking (40 days), followed by Arun-4 and S97TEYGHAYB(3), simultaneously. Similarly, in 2016 growing season, farmers' variety was early in both tasseling (35 days) and silking (38 days), followed by S97TEYGHAYB(3) in tasseling (45 days) and by S97TEYGHAYB(3) and Arun-4 in silking (48 days) (Table 2). The significant difference in days to tasseling and

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silking among the genotypes might be attributed to genotypic composition of genotypes. Difference in days to tasseling and silking among early maize genotypes were also observed by Prasai et al. (2014) and Kunwar et al. (2014). Result of combined analysis over year showed that there was highly significant influence of genotypes on days to tasseling and days to silking. Genotype farmers' variety was early in both tasseling (36 days) and silking (39 days), followed by S97TEYGHAYB(3) in tasseling (45 days) and by S97TEYGHAYB(3) and Arun-4 in silking (48 days) (Table 2). Similar result was also observed by Prasai et al. (2015).

Table 2: Days to tasseling and silking of early maize genotypes evaluated at RARS, Doti during summer seasons of 2015 and 2016

SN	Genotype	Days to tasseling			Days to silking		
		2015	2016	Combined	2015	2016	Combined
1	Earlymid Katamani	50	47	49	52	51	51
2	Rajahar Local Variety	48	49	49	50	53	52
3	S97TEYGHAYB(3)	45	45	45	48	48	48
4	POP-445/POP-446	46	50	48	49	53	51
5	COMPOL-NIBP	50	50	50	53	54	53
6	RC/POOL-17	47	48	48	50	52	51
7	S03TEY/LM	51	50	50	53	54	54
8	Arun-4	45	46	46	48	48	48
9	Farmers' Variety	37	35	36	40	38	39
10	ZM621/POOL-15	48	50	49	51	54	53
11	EEYC1	45	46	46	48	50	49
12	SO3TEY-LN/PP	49	51	50	52	55	53
13	SO3TEY-PO-BM	49	50	49	52	53	52
14	Across-99402	49	51	50	51	55	53
	Mean	47	48	47	50	51	51
	F test						
	Genotypes (G)	**	**	**	**	**	**
	Year (Y)			ns			**
	G × Y			*			ns
	$LSD_{(0.05)}$						
	Genotypes (G)	2.41	2.19	1.667	2.56	3.11	1.999
	Year (Y)						0.755
	G × Y			2.358			
	CV (%)	3.0	2.7	3.0	3.1	3.6	3.4

(Note: ns = non-significant at 5% level of significance, *=Significant at 5% level of significance, **= significant at 1% level of significance)

Number of plants and ears per hectare of land

The number of plants/ha and number of ears/ha were significantly influenced by genotypes in both growing seasons. During 2015 growing season, S97TEYGHAYB(3) recorded the highest number of plants/ha, followed by EEYC1. The highest number of ears/ha was recorded in SO3TEY-LN/PP, followed by EEYC1, Across-99402 and COMPOL-NIBP, simultaneously (Table 3). Similarly, during 2016 growing season, ZM621/POOL-15 recorded

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the highest number of plants/ha, followed by Rajahar Local Variety. The highest number of ears/ha was recorded in Rajahar Local Variety, followed by SO3TEY/LM. Combined analysis over years showed that Rajahar Local Variety, ZM621/POOL-15 and Across-99402 had the highest number of plants/ha simultaneously, whereas Rajahar Local Variety had the highest number of ears/ha, followed by SO3TEY/LM. The number of plants/ha was low as compared to the standard number of plants/ha in both growing seasons. This was mainly due to low germination of seeds in the experimental field. Besides this, continuous rain for 3 weeks after maize seeding further reduced the plant population in 2016 growing season as compared to the 2015 growing season. The reduced plant growth and vigor during 2016 growing season might have resulted in low translocation of photosynthates from source, causing low number of cobs/ha. The detail data is presented in Table 3.

Table 3: Number of plants and ears per hectare of early maize genotypes evaluated at RARS, Doti during summer seasons of 2015 and 2016

SN	Genotype	No. of plants/ha			No. of ears/ha		
		2015	2016	Combined	2015	2016	Combined
1	Earlymid Katamani	30370	32593	31481	35556	29630	32593
2	Rajahar Local Variety	38519	39259	38889	38519	42963	40741
3	S97TEYGHAYB(3)	42222	29630	35926	37778	25926	31852
4	POP-445/POP-446	24444	32593	28519	28889	14815	21852
5	COMPOL-NIBP	31852	22222	27037	39259	26667	32963
6	RC/POOL-17	32593	28148	30370	34815	25926	30370
7	S03TEY/LM	20000	31852	25926	37037	40000	38519
8	Arun-4	33333	35556	34444	31111	29630	30370
9	Farmers' Variety	21481	15556	18519	24444	14074	19259
10	ZM621/POOL-15	31852	45926	38889	25185	35556	30370
11	EEYC1	40741	34815	37778	39259	30370	34815
12	SO3TEY-LN/PP	30370	28148	29259	40000	28148	34074
13	SO3TEY-PO-BM	31111	25926	28519	37037	22963	30000
14	Across-99402	40000	37778	38889	39259	25926	32593
	Mean	32063	31429	31746	34868	28042	31455
	F test						
	Genotypes (G)	**	**	**	**	**	**
	Year (Y)			ns			**
	G × Y			**			**
	LSD $_{(0.05)}$						
	Genotypes (G)	6184	7650	4843	5792	5481	4147
	Year (Y)						1567
	G × Y			6849			5865
	CV (%)	11.5	14.5	13.2	9.9	11.6	11.4

(Note: ns = non-significant at 5% level of significance, *=Significant at 5% level of significance, **= significant at 1% level of significance)

Grain yield

The grain yield was significantly influenced by genotypes during both growing season (Table 4). During 2015 growing season, SO3TEY-PO-BM had the highest grain yield (4.33 t/ha),

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followed by COMPOL-NIBP (4.18 t/ha). Similarly, during 2016 growing season, Rajahar Local Variety had the highest grain yield (2.52 t/ha), followed by EEYC1 (2.46 t/ha). The higher grain yield in these genotypes might be attributed to higher number of ear harvested. The significant differences in grain yield of early maize genotypes were also recorded by Kunwar et al. (2014) and Prasai et al. (2014). The mean grain yield of 2016 growing season was lower than 2015 growing season. This was due to the continuous rainfall for 3 weeks after maize seeding, which affected the plant growth, vigor and yield. Excessive moisture stress during early vegetative stage severely affects the growth, anthesis and silking, and eventually results in poor kernel development and yield (Zaidi et al., 2004). Over the combined analysis, the highest grain yield was recorded in EEYC1 (3.17 t/ha), followed by COMPOL-NIBP (3.09 t/ha). Further, there was highly significant G × Y interaction for grain yield (Table 4).

Table 4: Grain yield of early maize genotypes evaluated at RARS, Doti during summer seasons of 2015 and 2016

SN	Genotype	Grain yield (t/ha)		
		2015	2016	Combined
1	Earlymid Katamani	2.95	1.65	2.30
2	Rajahar Local Variety	3.01	2.52	2.77
3	S97TEYGHAYB(3)	3.11	2.45	2.78
4	POP-445/POP-446	2.23	1.07	1.65
5	COMPOL-NIBP	4.18	1.99	3.09
6	RC/POOL-17	2.3	1.71	2.00
7	S03TEY/LM	3.41	1.78	2.60
8	Arun-4	2.83	2.33	2.58
9	Farmers' Variety	1.41	0.78	1.09
10	ZM621/POOL-15	2.39	2.06	2.22
11	EEYC1	3.88	2.46	3.17
12	SO3TEY-LN/PP	3.52	1.50	2.51
13	SO3TEY-PO-BM	4.33	1.46	2.90
14	Across-99402	3.98	1.26	2.62
	Mean	3.11	1.79	2.45
	F test			
	Genotypes (G)	**	**	**
	Year (Y)			**
	G × Y			**
	$LSD_{(0.05)}$			
	Genotypes (G)	0.75	0.44	0.478
	Year (Y)			0.181
	G × Y			0.675
	CV (%)	14.3	14.7	16.9

ns = non-significant at 5% level of significance, *=Significant at 5% level of significance, **= significant at 1% level of significance.

The highly significant G × Y interactions indicated that the genotypes performance differs across the testing years, which might be due to difference in climatic condition of study area during crop growth period. Prasai et al. (2015) also concluded the similar findings from their earlier research.

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CONCLUSION

Evaluation of maize genotypes is important task for maize development program. The Early maize genotypes showed considerable variation in grain yield. The genotypes, EEYC1, COMPOL-NIBP, SO3TEY-PO-BM and S97TEYGHAYB(3) were superior early maize genotypes for river basin agro-environment of Far-Western Nepal.

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AUTHOR CONTRIBUTIONS

B.P.J. performed the experiments and collected data; B. D. analyzed the data and wrote the paper, and K.P.S. and J. S. revised the article for the final approval of the version to be published.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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Effects of storage structures and moisture contents on seed quality attributes of quality protein maize

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ABSTRACT

The study was aimed to examine the effects of various storage structures and moisture contents on seed quality attributes of quality protein maize seed. The quality protein maize (QPM-1) seed was tested in conventional seed storage containers (Fertilizer sack and earthen pot) and the improved hermetic ones (Metal bin, Super grain bag, and Purdue Improved Crop Storage (PICS) bag) at Seed Science and Technology Division, Khumaltar, Nepal during February, 2015 to January 2016. Ten treatments comprising 5 storage devices in two moisture regimes (11% and 9%) replicated thrice and laid out in Completely Randomized Design (CRD). Data on temperature, relative humidity (RH), germination, electrical conductivity (EC), seed moisture content (MC) were collected bimonthly. The conventional containers were found liable to the external environmental condition whereas the hermetic structures observed with controlled RH level below 40% in all combinations. Electrical conductivity (EC) for seed vigor showed that hermetic containers provide higher seed vigor than the conventional ones. Up to 4 months all treatments were found statistically at par for germination. A significant difference was observed in each treatment after 4 months where PICS bag & Super grain bag showed best germination followed by metal bin while fertilizer bag & earthen-pot showed poorer and poorest germination respectively till one year. Almost all treatments with lower MC showed better results than the treatments with higher MC. A negative correlation (R^2=69.7%) was found between EC and Germination. All six figures from 2 to 12 months on MC showed statistically different where hermetic plastic bags were found maintaining MC as initial whereas MC of fertilizer bags and earthen pot was spiked than the basal figure. The finding evidenced that the hermetic containers and low MC are the seed storage approaches for retaining the quality of seed even in an ambient environmental condition for more than a year.

Keywords: Seed quality, Germination, storage containers, Electrical conductivity, Moisture content

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INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crop after rice and a major feed crop in Nepal (KC et al., 2015). Despite the implementation of various seed related projects and active involvement of public and private institutions; still the country has been suffering from unavailability of quality seeds. Quality seed demand in Nepal is apparently tremendous, where lion's share of seeds are imported and country's import has been hiking each year. The official record of Seed Quality Control Centre (SQCC) in 2015 shows that 2745 metric tons of seed was traded in where 1025 million of Nepalese currency redeemed. Formal sector contributes less than 10% of seed demand whereas Informal sector, farmer-to-farmer seed exchange mechanism has been contributing 20-50% of seed demand. Seed replacement rate (SRR) for maize is below 15 % (Joshi, 2015). Hence, production and proper storage of quality seed in community level is regarded as pivotal step for ameliorating the quality seed scarcity.

Seed is a fragile living entity; hence storability is greatly influenced by the subjected abiotic and biotic environmental conditions. The principal environmental factor that is responsible for seed quality deterioration are temperature, relative humidity, atmospheric conditions of storage containers and moisture content of the seed. The hygroscopic nature of maize seed sometimes make them unsafe for storage in open container (Adetumbi et al., 2009). In humid tropical region, at temperature 25°C and above and 65-70% relative humidity, storage of maize seed for more than 3-4 months could be detrimental for seed viability and vigor unless proper container and moisture level maintained (Abba & Lavato, 1999). Moreover, Maize weevil (*Sitophilus zeamais* Mostsch.) and Angoumois grain moth (*Sitotroga cerealella* Oliv.) were major insect pests found as limitations to be considered in maize storage in Nepal (Sherpa et al., 1997, G.C., 2006). Similarly, 10-20% quantitative loss of maize is recorded during storage in western Nepal due to poor storage technique that incite deterioration of viability and vigor of maize seed (Bhandari et al., 2015).

Seed quality, viz. viability and vigor decreases under long storage conditions due to ageing. The relationship between laboratory and field germination depends directly on environmental conditions and procedures adopted for field sowing. The capacity of laboratory tests estimating field seedling emergence potential inversely related with ideal environmental conditions, and sometimes becomes null under extremely unfavorable conditions (Egli & TeKrony, 1996). The EC test is one of those used to evaluate the seed vigor. The relationship between water content, organizational level of seed cellular membranes and quantity of leachates in the soaking solution serve as the theoretic base of the EC test. Thus, lower the amount of leachates released to the soaking solution, indicates high seed vigor and vice versa (Adriana et al., 2012; Powell, 1988). Unlike germination and Accelerated Ageing Test, the conductivity test can be conducted within 24 hours with an instrument in field level which is regarded as easy and effective method to assess the quality of seed lot rapidly with reliability (Bewley & Black, 1994). Studies with pea, soybean, cotton, Phaseolus bean, maize and small- seeded crops found that seed leachate conductivity test indicates both standard germination and seed vigor in reliable way (Matthews & Powell 2006).

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Besides quality seed supply, the environment and pests are the major cons for maintaining the proper seed quality for longer period. This experiment was thus designed to evaluate the functionality of existing common seed storage devices, earthen pot and plastic sacks with improved ones, metal bin, Super grain bag, and PICS bag.

MATERIALS AND METHODS

The experiment was conducted in laboratory of Seed Science and Technology Division (Longitude 85°10’ E and Latitude 27°39’N; Altitude, 1335m), Nepal during February 2015 to January, 2016.

A maize variety, quality protein maize-1 (QPM-1) was selected and stored at two moisture regimes;

- M1: 11% moisture content
- M2: 9 % moisture content

Moisture content of maize was maintained by applying initial sun drying method and further a week desiccation with the help of zeolite beads in a recommended amount using drying bead calculation software. Seed maintained at two different moisture regimes (M1 and M2) with 98% initial germination were stored in five different storage containers as follows:

- S1:Metal Bin (Made up of 24 gauze plane zinc sheet)
- S2: Plastic sack or fertilizer bag (a high density polyethylene (HDPE) fertilizer bag with 100 gauge of low density polyethylene (LDPE) film laminated internally)
- S3: Super Grain Bags
- S4: Earthen pot or bin (locally called Ghyampo)
- S5: Purdue Improved Crop Storage (PICS) bag.

Ten treatments comprising 5 storage devices (S1, S2, S3, S4, and S5) in each seed moisture regime (moisture regimes M1 and M2) replicated thrice and laid out in Completely Randomized Design (CRD). A digital hygrometer was incorporated inside the each container in order to record the temperature and RH and all sets were stored in ambient condition. The initial seed quality attributes like germination, EC, and seed moisture content in each treatment were analyzed at every two months interval.

Hygrometer readings for temperature and RH were recorded just before sampling. Seed sampling from each treatment for germination, seed MC and EC was carried out in bimonthly interval. Germination was conducted in germination paper by using between paper (BP) methods. Oven method was used for the assessing the moisture content of the seed as described by ISTA (International Seed Testing Association) rule. The EC was checked and recorded randomly in three replications of each treatment. According to the method of seed vigor testing (ISTA, 2011), fifty seeds in each treatment were weighed and placed in 250 ml distilled water containing beaker. Further, beakers were sealed using aluminum foil and was kept at 20°C for 24 h. The electrical conductivity of the seed leachates was measured using Hanna’s EC meter (HI 99300) and results of EC was expressed in µSiemens $cm^{-1}g^{-1}$, which was calculated formula.

$$EC\ (\mu S cm^{-1} g^{-1}) = \frac{\text{Conductivity Reading } (\mu S cm^{-1})\text{-background reading}}{\text{Weight (g) of replicate}}$$

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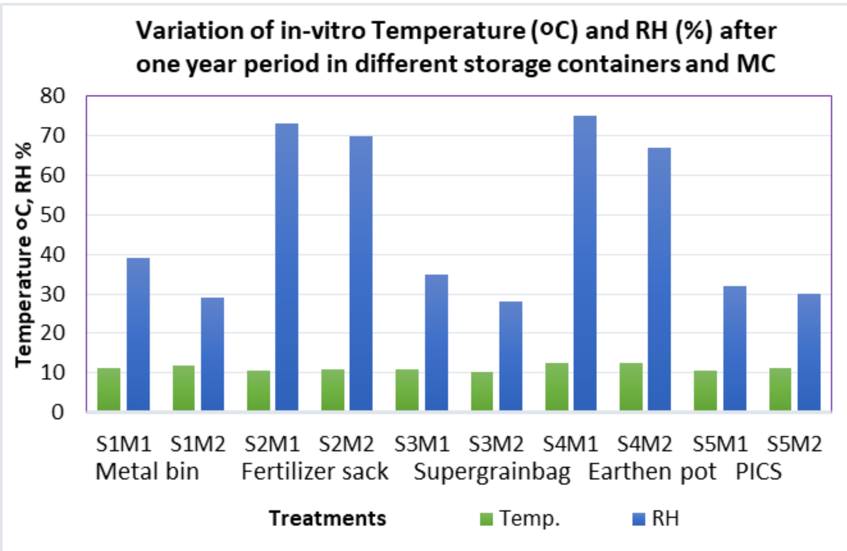
Data collected on various parameters were portrayed and analyzed by using MS-excel, Gen-stat and mean separation was done by Minitab.

RESULTS AND DISCUSSION

The hygrometer readings revealed that the temperature was more or less constant with respect to the storage room temperature that is 10-12∘C. Moreover, RH for the opened containers, viz. plastic sack and earthen bin also remained concurrent (around 70%) with the ambient RH while the Metal bin, Super grain bag and PICS bags were found with controlled atmospheric environment internally where RH accounted for below 40% (Figure 1).

Fig 1: Variation of in-vitro Temperature (∘C) and RH (%) after one year period in different storage containers and MC in Khumaltar, 2015-2016.



In addition to this, the RH for the hermetic containers with low MC was also found to be lesser RH than the same containers with higher MC%.

This suggests that the hermetic containers meliorate the storability of seeds in low moisture content as per the thumb rule proposed by Harrington that the sum of temperature in Fahrenheit and RH in percentage should be less than 100.The safe RH for seed storage is 40% (Harrington,1960). So in the given MC and temperature, these hermetic containers were found better for mitigating the RH% in humid sub-tropical climatic condition.At the storage of one year period, the electrical conductivity of stored maize seed in hermetic containers in below 60 $\mu Scm^{-1}g^{-1}$ were found significantly lower, whereas the conductivity for storage in fertilizer bag and earthen bin was found spiked beyond 140 $\mu Scm^{-1}g^{-1}$with highly significant ($p \leq 0.01$) (Figure 2). Unlike maize, Soybean seed lots that present EC test values between 60 and 70 $\mu Scm^{-1}g^{-1}$ are considered high vigor seed lots; values between 70 and 80 $\mu Scm^{-1}g^{-1}$ are presented by intermediary vigor seed lots (Vieira, 1994). On the other hand, in the United States of America, seeds with EC values higher than 150 $\mu Scm^{-1}g^{-1}$ are classified as low vigor seed lots and considered inadequate for sowing (AOSA, 1983).These figures bolstered the current finding to a convinced extent, although crop seed was different.

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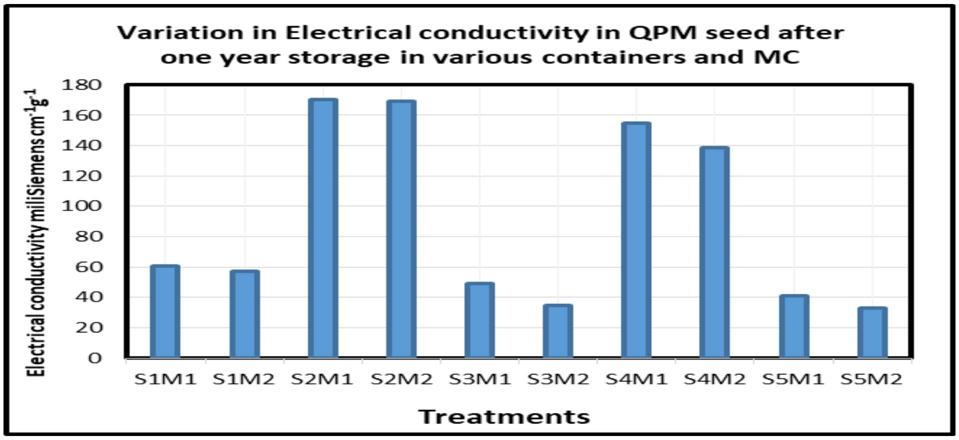
Fig 2: Variation in Electrical conductivity in QPM seed after one year storage in various containers and MC in Khumaltar, 2015-2016.



Significant difference was observed in the germination in QPM-1 among the 10 treatments after 4-months. Instead of diverse mean values among the treatments, no any statistical discrepancies were found until 4 months period. After 6-months, the germination was found statistically different in Ghyampo (S4), which revealed poor germination than other 4 structures and MC. In 8th month, Metal bin (S1), super-grain bag (S3), and PICS (S5) showed superior germination than that of Fertilizer bag (S2) and Earthen pot (S4) similar trend was also seen in both results from 10th and 12th month (Table 1).

Table 1. Effect of storage structure and moisture content on germination in QPM-1 for yearlong storage in SSTD, Khumaltar, 2016.

Ent No.	Treatments	Germination % of Quality Protein Maize					
		2 Month	4 Month	6 Month	8 Month	10 Month	12 Month
1	S1M1	95	96	94^{a}	95^{a}	94^{a}	89^{a}
2	S1M2	95	96	97^{a}	96^{a}	88^{ab}	92^{a}
3	S2M1	96	95	95^{a}	88^{ab}	84^{ab}	63^{b}
4	S2M2	96	95	97^{a}	83^{b}	72^{b}	69^{b}
5	S3M1	96	96	98^{a}	95^{a}	94^{a}	94^{a}
6	S3M2	96	96	96^{a}	96^{a}	95^{a}	95^{a}
7	S4M1	94	93	82^{b}	53^{c}	37^{c}	29^{d}
8	S4M2	95	93	85^{b}	65^{c}	41^{c}	38^{c}
9	S5M1	96	95	95^{a}	94^{ab}	96^{a}	95^{a}
10	S5M2	96	94	96^{a}	96^{a}	94^{a}	96^{a}
F-value		0.219	0.239	0.013	<0.001	<0.001	<0.001
LSD (0.05)		1.726	2.989	8.034	11.93	18.89	7.77
CV (%)		0.8	1.4	3.9	6.4	11.1	4.6
Grand mean		96	95	94	84	77	76
SEM(±)		0.775	1.342	3.606	5.35	8.48	3.48
F test		NS	NS	*	**	**	**

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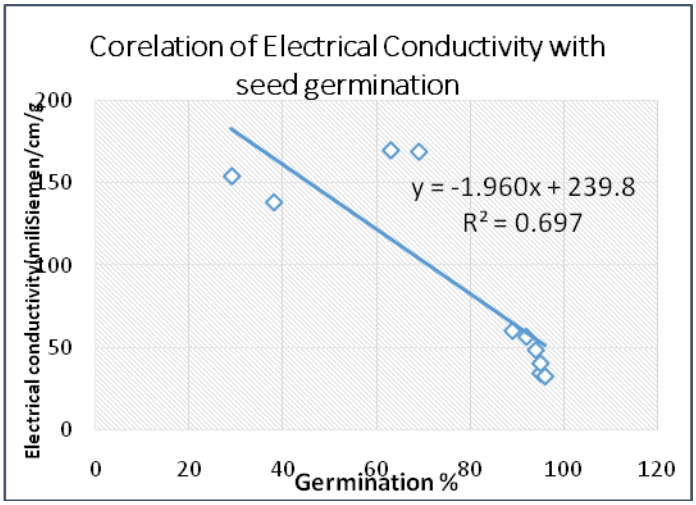
Means followed by the same alphabets on superscript are not significant by Fisher LSD Method in 95% Confidence. * ($p \leq 0.05$), ** ($p \leq 0.01$), (NS-Non-Significant)

Many hermetic research corroborated on this findings. Germination above 80% in maize also recorded up to 15 months in 500 gauge plastic bags which as stored in 12% and 8% MC (Mettananda et al., 2001).

Fig 3: Correlation of Electrical conductivity and germination in QPM seed from various containers and MC in one year storage in Khumaltar, 2015-2016.



A reciprocal relationship was obtained by plotting the electrical conductivity and germination of 12-months storage QPM-1 seed sample. Irrespective of other things, 69.7% germination value was found indirectly proportional to EC reading. Similar trend with rather good results in soybean (r= -0.89 and -0.92) (Oliveira et al., 1984); soybean with r=-0.67 to -0.79 (Yaklich et al., 1979), long bean with correlation coefficient -0.80 and -0.86 (Abdullah et al., 1991);in Phaseolus with r= -0.80 and -0.87 (Powellet al., 1986); in cabbage and cauliflower with r^2 value 0.79 to 0.96 (Mirdad et al., 2006) have been found documented (Figure 3).

On the moisture content, for one year period, each data showed highly significant variation in means both in structures and moisture content. Generally, the hermetic containers were found with less fluctuated figures than non- hermetic containers, viz., Fertilizer sack (S2) and Earthen pot (S4) as compared with the initial moisture contents (M1& M2) 11% and 9%. The moisture contents on these containers were found fluctuated with the storage condition as they are highly influenced by the external environmental conditions. The detailed data of each treatment is presented in table 2. Similar supported works revealed in hermetic 500 gauge plastic bags, where 12% MC was just increased to 12.5% and 13% in 10 month and 15 month storage in ambient room temperature in Srilanka (Mettananda et al., 2001). Similarly, Data logger placed inside the hermetic bags-PICS and woven polypropylene bag did not get fluctuate on its internal environmental profiles in two different locations and found no penetration of moisture too. (Lane & Woloshuk, 2017).

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Table 2. Effects of seed moisture content and storage structure on moisture content of QPM-1 for yearlong storage in SSTD, Khumaltar, 2016.

Ent No	Treatments	Moisture % of Quality Protein Maize					
		2 Month	4 Month	6 Month	8 Month	10 Month	12 Month
1	S1M1	10.41^{c}	9.93^{d}	9.65^{c}	10.3^{c}	10.23^{cd}	10.24^{cd}
2	S1M2	9.43^{d}	8.87^{e}	8.10^{e}	8.97^{c}	9.46^{d}	9.88^{de}
3	S2M1	12.3^{a}	12.08^{a}	12.07^{a}	12.82^{ab}	12.74^{b}	13.06^{b}
4	S2M2	11.76^{b}	10.9^{b}	11.64^{ab}	12.91^{ab}	13.97^{ab}	13.59^{ab}
5	S3M1	10.38^{c}	9.93^{d}	9.49^{cd}	9.51^{c}	11.07^{c}	10.97^{c}
6	S3M2	9.38^{d}	9.14^{e}	8.25^{e}	9.17^{c}	9.79^{cd}	9.66^{de}
7	S4M1	11.98^{ab}	12.02^{a}	12.31^{a}	14.1^{a}	14.56^{a}	14.32^{a}
8	S4M2	10.05^{c}	10.43^{c}	11.07^{b}	12.37^{ab}	13.07^{b}	13.0^{b}
9	S5M1	10.35^{c}	9.66^{d}	9.69^{c}	9.72^{c}	9.90^{cd}	10.08^{cde}
10	S5M2	9.01^{d}	9.14^{e}	8.31	9.17^{c}	9.29^{d}	9.22^{e}
F-value		<0.001	<0.001	<.001	<0.001	<0.001	<0.001
LSD (0.05)		0.51	0.384	0.8481	1.556	1.46	0.937
CV (%)		2.2	1.7	3.8	6.5	5.7	3.7
Grand mean		10.50	10.21	9.96	10.80	11.41	11.40
SEM(±)		0.227	0.172	0.381	0.698	0.665	0.42
F-test		**	**	**	**	**	**

Means followed by the same alphabets on superscript are not significant by Fisher LSD Method in 95% Confidence. * ($p \leq 0.05$), ** ($p \leq 0.01$), (NS-Non-Significant)

CONCLUSION

The study found that Hermetic storage containers, PICS bag, Super grain bag, and Metal-bin corroborated superiority over fertilizer sack and earthen pot for seed storage and retaining quality in both germination and vigor in lower moisture content for yearlong storage in maize. Hence, maintaining low MC and using hermetic devices significantly contributes in maintaining the viability and vigor of seeds in sub-tropical environmental condition. Mass utilization of such containers for seeds storage not only protect seeds from biotic and abiotic deterioration but also helps in conserving seeds for two consecutive growing seasons that eventually reduces the demand and procurement of seeds in successive season. Moreover, EC test for rapid appraisal of seeds lot can be an effective tool that can validate the seed quality in significantly shorter period of time with limited resources.

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AUTHOR CONTRIBUTIONS

R. A. proposed the project. T.B.G. designed the experiment. S. K. collected the data. G. B. and J. S. analyzed the data and wrote the paper, and revised the article for the final approval of the version to be published.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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Analysis of genetic diversity among the maize inbred lines (*Zea mays* L.) under heat stress condition

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ABSTRACT

High temperature adversely affects the plant physiological processes: limits plant growth and reduction in grain yield. Heat stress is often encountered to spring sowing of maize in spring season. Twenty maize inbred lines were studied for days to 50 % anthesis and silking, anthesis–silking interval, leaf firing, tassel blast, SPAD reading and leaf senescence, plant and ear height, leaf area index, ear per plant, cob length and diameter, number of kernel/ear, number of kernel row/ear, number of kernel row, silk receptivity, shelling percentage, thousand kernel weight and grain yield in alpha lattice design at National Maize Research Program at Rampur, Chitwan,Nepal with the objective to identify superior heat stress tolerant lines. Analysis of variance showed significant difference for all the traits. Result of multivariable analysis revealed that twenty inbred lines formed four clusters. The resistance inbred lines and susceptible inbred lines formed different clusters. The members of cluster 4 were found to be tolerant to heat stress due to they had lowest value of tassel blast, leaf firing, and leaf area index with highest value of cob diameter and length, ear per plant, number of kernel row/ear, number of kernel/ear, number of kernel row, shelling percentage, silk receptivity and grain yield whereas as members of cluster 1were found most susceptible due to they had longer anthesis silking interval, with maximum tassel blast and leaf firing along with no grain yield under heat stress condition. From this study inbred lines RL-140, RML-76, RML-91 and RML-40 were found most tolerant to heat stress. These inbred lines belonging to superior cluster could be considered very useful in developing heat tolerant variety and other breeding activities.

Keywords: Maize (*Zea mays L.*), Genetic divergence, Heat stress, Multivariable analysis

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INTRODUCTION

Maize (*Zea Mays* L.) is an important cereals crop belongs to the tribe Maydeae, of the grass family, Poaceae and popularly known as the 'queen of cereals' (Dhaka et al., 2010).It is important cereal crop worldwide after wheat and rice in worldwide and second most staple food crop both in term of area and production after rice in Nepal. It is grown in 8, 91,583 ha producing 2.2 million tons, with an average yield of 2500 kg/ha (MoAD, 2016).Beside direct consumption as food, it is also an important source of industrials raw materials example the manufacture a starch, dextrose, oil sugar, syrup, enzymes, adhesive paper and plastic. Maize demand will be double in developing world in 2050 and it predicted as crop of greatest production globally and in developing world by 2025 (Rosegrant et al., 2008).

Climate change effects such as global warming is major challenge on crop production and identify possible ways that would allow yield ceilings to shift by developing improved thermos tolerant cultivars. Therefore these efforts are particularly important in south Asia, where current production systems are not sustainable and could be adversely impacted by climate change in the near future (Niyogi et al., 2010). Heat and drought stress have emerged as a common problem worldwide which can reduce maize crop productivity (Ali et al., 2015).A record drop in maize production was reported in many maize-growing areas of the world (Van der Velde et al., 2010).It is predicted that maize yield might be reduced up 70 % due to increasing temperatures (Khodarahmpour et al., 2011).

Genetic diversity analysis is imperative in crop improvement and can be studied through morphological, biochemical and molecular markers. Morphological characterization for genetic divergence among genotypes is considered an initial step (Khan et al., 2014).Therefore morphological data has play key role in management of genetic resources. To management of genetic resource study relationships and description and classification of germplasm the morphological characterization is the first step (Smith & Smith, 1989).Cluster analysis is frequently used to classify maize accessions and can be used by breeders and geneticists to identify subsets of accessions which have potential utility for specific breeding or genetic purposes (Rincon et al., 1996).

The main aim of using a cluster technique in plant breeding trials is to group the varieties into several homogeneous groups such that those varieties within a group have a similar response pattern across the locations. Many researchers have used principal component analysis to assess genetic variability among maize genotypes because it retrieves small numbers of components that account for most of the variations in the data (Asare, 2016).The objective of the research was to identify superior heat stress tolerant inbred lines after clustering them based on their response to heat stress condition.

METERIALS AND METHOD

The research was conducted at National Maize Research Program (NMRP) of Rampur, Chitwan Nepal during spring season from February 24, 2015 to July 2016, geographically located at 27º 37' North Latitude and 84 º 29' East longitude at an altitude of 225 meter above sea level. This site contains only sandy loam soil with acidic reaction. This research location is characteristics of subtropical climate. The plant materials were collected from National Maize Research Program

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(NMRP).The list of inbred lines along with pedigree information included in the study is presented in Table 1.

Table 1: Names and pedigree information of maize inbred lines used for heat stress research at NMRP Chitwan (2016).

S.N	Inbred line of maize	Pedigree sources/origin	S.N	Inbred line of maize	Pedigree sources/origin
1	NML-2	CML-430	11	RL–101	UPAHAR-B-20-2-3-1-1
2	RML–4	CA00326	12	RML–24	CA00304
3	RML–32	CA00320	13	RML–40	CML-427
4	RML–95	PUTU-17	14	RML–57	CLQG6602
5	RML–86	PUTU-20	15	RL–107	UPAHAR-B-20-2-4-3-1
6	RML–17	CML-287	16	RML–20	CA-34503
7	RML–96	AG-27	17	RML–76	CLRCYQ007
8	RL–105	UPAHAR-B-20-2-4-1-1	18	RML–7	CML-413
9	RL–111	UPAHAR-B-31-1-1-1-1	19	RML–91	PUTU-19
10	RML–115	PUTU-17	20	RL–140	POOL-21-12-1-2-2-1-1

Field experiment was conducted in alpha lattice design. There were two conditions: normal and plastic house (for heat stress), each condition replicated twice. Each replication comprised four blocks consisting of five plots each. Each plot was 3 meter in length 0.6 meter wide. Each plot had one row with spacing 20 cm between rows, inter block gap was 0.5 m was maintained. Each plot contained single row with spacing 60×20 cm and consisted 15 hills, each of two seed were sown, one of whose seedling were removed at the six leaves stage. The dose of chemical fertilizer applied was 120:60:40 kg NPK per hectare. Fertilizer were applied prior to sowing at rate of N 60 kg/ha, P 60 kg/ha and K 40 kg/ha and additional side dressing of 30 N kg/ha were applied at the two times in six leaves stage and knee high stage of maize. The irrigation was done three important stage, knee high stage, tasseling stage and milking stage. To created heat stress condition maize study half of field was controlled heating imposed using two plastic (120gsm) houses were used two week just prior to the onset of reproductive period up to the crop harvesting. Maximum mean temperature 46.2°C in April in heat stress condition whereas as normal condition was 37.23°C and similarly for May month in maximum mean temperature was 43.28°C whereas in normal condition 34.54°C means mean temperature 8-9°C higher in plastic house at time of flowering, pollination and grain filling periods responsible for creates heat stress condition as shown in Fig 1.Partial opening top side of tunnel was done for control relative humidity inside tunnel to avoid any possible disease outbreak.

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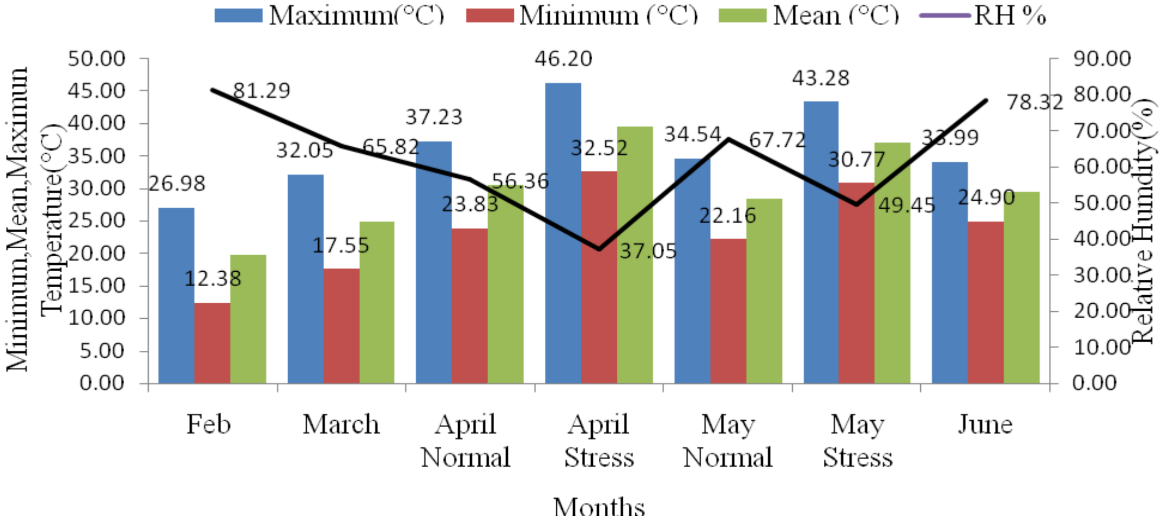

Figure 1: Weather and stress data during the growing period of maize at NMRP, Chitwan (2016).

Data collection

Data on days to 50% anthesis, days to 50% silking and ears per plot, leaf firing, tassel blast, leaf senescence were recorded on plot basis. Whereas, ear height (cm), number of kernels/cob, number of kernel row, number of kernel row/ear, SPAD reading, leaf area index, silk receptivity, thousand kernel weight (g) and shelling per cent were recorded on five selected representative plants. The sample cobs were shelled, cleaned and grain weight and shank weight were recorded to calculate the shelling percent. Thousand kernel weight was measured by counting 1000 grains from the bulk of each plot after shelling and weighed in grams after the moisture was adjusted to 15%. Anthesis-silking interval (ASI) was calculated by subtracting the number of days taken for 50% anthesis from the number of days taken to50% silk emergence. Leaf area index was calculated by total leaf area divided by land area and multiply by correction factor (0.75). Silk receptivity was recorded by total number of fertilized grains per ear divided by number of potential grain per ear. Leaf firing was obtained by the counting the number of plants that showed leaf firing symptoms (younger leaves near tassel burnt or dried) in the total number of plants in a particular plot and was expressed in percentage. Tassel blast was obtained by the counting the number of plants that showed tassel blast symptoms (tassel dried with partial or no pollen shedding) in the total number of plants in particular plot was expressed in percentage. Grain yield was calculated using formula adopted by Carangal et al. (1971) and Shrestha et al. (2015) by adjusting the grain moisture at 15% and converted to the grain yield per hectare.

Statistical Analysis

The data recorded on different parameters from in heat stress field were first tabulated and processing in Microsoft excel (MS- Excel, 2010), then subjected to restricted maximum likelihood (REML) tool in GenStat to obtain ANOVA. These collected data were subjected to cluster analysis (average linkage method) and principal component analysis using statistical software packages of Minitab ver.17.

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RESULTS

The present study genetic diversity for heat stress tolerance was analyzed among 20 maize inbred lines on the basis of 19 agro morphological traits. The result of descriptive analysis (Table1) showed that leaf firing percentage had highest variation (52.3) fallowed by tassel blast percentage (22.93), anthesis silking interval (21.9), SPAD (14.22).Among trait plant physiological maturity showed the lowest variation (1.5). Significant variation among inbred lines differences for grain yield and anthesis silking interval, SPAD reading and leaf senescence, tassel blast and leaf firing percentage, plant and ear height, leaf area index, ear per plant, cob length and diameter, number of kernel/ear, number of kernel row, number kernel/ear, silk receptivity, shelling percentage, thousand kernel weight under heat stress condition. The mean value of observed traits anthesis silking interval, leaf area index, leaf firing, tassel blast, leaf senescence, SPAD, plant height, ear height, plant maturity, cob length, cob diameter, number of kernel row/ear, number kernel/ear, number of kernel row, silk receptivity, shelling percentage, thousand kernel weight and grain yield as presented in Table 1.Inbred lines RML-91 (716.8 kg/ha) fallowed by RL-140 (702.9 kg/ha) and RML-76 (689.5 kg/ha) produces maximum yield whereas as inbred lines NML-2, RL-105, RL-111, RML-115, RML-24, RML-4, RML-86, and RML-95 produces barren cob under heat stress condition.

Table 1: Descriptive statistics of agro morphological traits of 20 maize inbred lines at NMRP, Rampur, Chitwan (2016 spring)

Statistics	Mean	F –test	CV%	LSD	Statistics	Mean	F –test	CV%	LSD
ASI	3.8	*	21.9	1.8	CD	1.677	**	14.66	0.532
LAI	2.64	*	12	0.7	CL	6.89	**	12.97	1.931
LF	18	*	52.3	20.8	NKRE	6.64	**	7.2	1.037
TB	35.6	**	22.93	17.64	NKE	42.1	**	21	19.21
LS	63.8	**	12.4	17.2	NKR	7.82	**	13.52	2.284
SPAD	38.16	*	14.22	11.723	SR%	17.23	**	11.57	4.31
PH	129.9	*	7.91	22.21	SP%	26.79	**	14.7	8.56
EH	66.6	**	8.13	11.7	TKW	164.8	**	6	21.61
PM	106.5	**	1.5	3.432	GY	316	**	8.62	58.89
EPP	1.168	*	15	0.379					

* and **, significant at 5 % and 1 % probability level.

Cluster Analysis

All the inbred lines were clustered using day to 50 % tasseling and silking, anthesis–silking interval (ASI), leaf firing, tassel blast, SPAD reading and leaf senescence, plant and ear height, leaf area index, ear per plant, cob length and diameter, number of kernel/ear, number of kernel row, number kernel/ear, silk receptivity, shelling percentage, thousand kernel weight at heat stress condition as variables. The dendrogram reveled four clusters with minimum of 22.47 % similarity level in UPGMA Clustering. The distance between the clusters centroid was found highest between clusters 1 and 4 and lowest between clusters 2 and 4 is presented in Table 2.The clusters were divided into two groups: group A and Group B. Group A consisted of one cluster named as cluster one whereas group B consisted of three clusters namely Cluster2, Cluster 3 and cluster 4. Cluster 1 consisted of 8 lines named as NML-2, RL-105, RML-24, RL-111, RML-4,

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RML-86, RML-95 and RML-115 which represent 40% of total lines. Inbred lines grouped in this cluster had longer anthesis silking interval, with maximum tassel blast and leaf firing along with zero value for grain yield including cob length, cob diameter and length, number of kernel row/ear, number of kernel/ear, number of kernel row, shelling percentage, silk receptivity and thousand kernel weight. The lines of this cluster are most susceptible to heat stress. Cluster 2 consisted of 5 lines named as RL-101, RML-17, RML-32, RML-96 and RML-7, 25% of total lines was characterized with had highest leaf senescence fallowed by thousand kernel weight and lowest for cob diameter and length, ear per plant, number of kernel row/ear, number of kernel/ear and number of kernel row. The inbred lines categorized into cluster 3 were RL-107, RML-20 &RML-57, 15 % of total lines had shorter plant and ear height, late physiological maturity and highest for ear per plant. Cluster 4 consisted of 4 lines named as RL-140, RML-76, RML-91 and RML-40, 20 % of total lines were characterized by lowest value of tassel blast, leaf firing, leaf area index with highest value of cob diameter and length, ear per plant, number of kernel row/ear, number of kernel/ear, number of kernel row, shelling percentage, silk receptivity and grain yield in heat stress condition. Since this cluster of lines had superior trait value for heat stressed condition, these lines may be of interest to researchers.

Table 2: Distance among the different cluster centroid of maize under heat stress at NMRP, Rampur,Chitwan (2016).

	Cluster1	Cluster2	Cluster3	Cluster4
Cluster 1	0	614.977	398.599	750.397
Cluster 2		0	247.245	158.825
Cluster 3			0	399.583
Cluster4				0

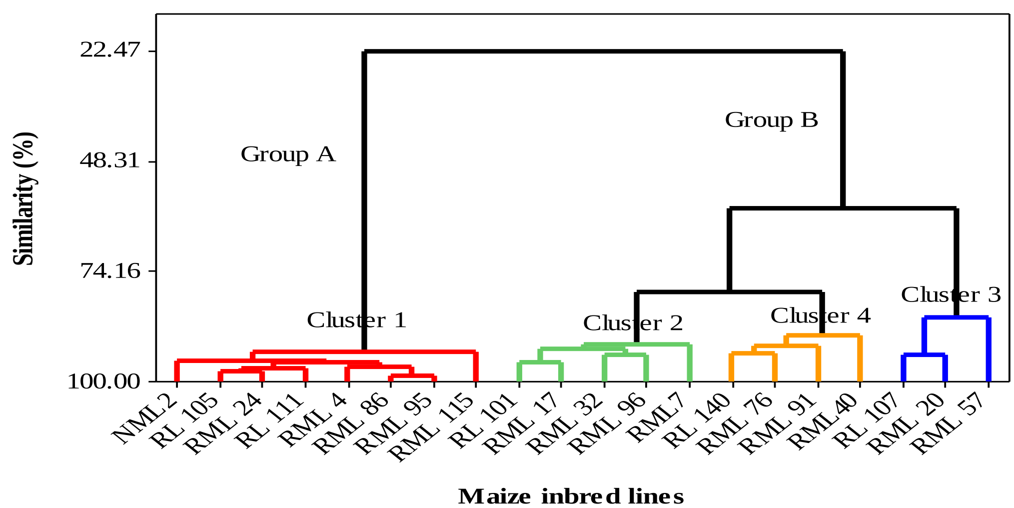

Figure2: Cluster analysis of 20 maize inbred lines evaluated for agro-morphological traits under heat stress at NMRP, Rampur, Chitwan (2016).

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Table 3: Mean of Clustering of 20 Maize inbred lines under heat stress condition at NMRP, Rampur, Chitwan (2016).

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Centroid
No. of inbred lines	8	5	3	4	20
Anthesis silking interval	5.06	2.8	2.66	3.37	3.8
Leaf area index	2.83	2.55	2.53	2.47	2.64
SPAD Chlorophyll	33.209	41.31	42.93	40.56	38.16
Leaf firing	26.35	14.88	11.6	5.75	17.13
Tassel blast	47.51	28.64	27.33	26.825	35.63
Plant height	131.25	130.78	125.133	129.45	129.85
Ear height	71.06	65.74	59.833	63.8	66.59
Physiological maturity	107.563	105	104.16	107.75	106.47
Leaf sensense	58.75	72	68.33	60	63.75
Ear per plant	1.18	1.066	1.323	1.143	1.16
Cob diameter	0	2.69	2.77	2.93	1.677
Cob length	0	11.46	8.43	11.64	6.37
Number of kernel row per ear	0	11.04	10.76	11.35	6.64
Number of kernel row	0	12.26	13.26	13.825	7.82
Number of kernel per ear	0	56.46	49.73	102.37	42
Silk receptivity	0	27.1	21.76	35.95	17.23
Shelling percentage	0	51.17	25.44	50.89	26.78
Thousand kernel weight (g)	0	285.32	260.467	271.825	164.76
Grain yield (kg ha^{-1})	0	537.68	293.4	688.05	316.04

Principal Component Analysis

The PCA showed close resemblance with clustering and partitioned the total variance into 4 PCs having eigen value >1 explanining 85.9 % of total vaiation with eigen value between 10.935 to 1.293, among 20 lines of maize under heat stress,However, the remaning componnent contributed only 14.4 % towards total diversity for this set of maize lines.The first three pricipal component (PC1) which explained 79.2 % was associated mainly by anthesis silking interval (0.257),tassel blast(0.229), leaf firing (0.216) and leaf area index (0.120) with negative loading with grain yield, cob diameter (-0.295),cob length (-0.275),number of kernel/ear (-0.275),number of kernel/row (-0.297),number of kernel/ear (-0.298),shelling percentage(-0.276),silk receptivity (-0.295) and thousand kernel weight(-0.297) due to some heat susceptible lines in this cluster. Second principal (PC2) was responsible for about 13.4 % was mainly related to positively for leaf firing (0.239), physiological maturity (0.258). SPAD(0.145) and anthesis silking interval (0.106)with negatively for leaf area index (-0.273),tassel blast (-0.176),ear height(-0.538),ear per plant(-0.258),leaf senescence(-0.149) and grain yield(-0.008).PC3 contributed 8.3%with major positive contributor are leaf senescence (0.585) fallowed by leaf firing (0.218) whereas negatively associated with anthesis-silking interval (-0.104) leaf area index(-0.283),plant height(-0.147),ear height(-0.186),physiological maturity(-0.565) and grain yield(-0.135).PC4 accounted 6.8 % of the total variation was mainly negative association with, leaf area index (-0.489),leaf firing (-0.024),tassel blast (-0.139), leaf senescence(-0.397),SPAD(-0.201),shelling percentage(-0.058) and thousand kernel weight(-0.009) and positive association with anthesis-silking interval (0.154), grain yield (0.024), ear per plant (0.708),silk receptivity (0.030), plant height (0.708),

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number of kernel row/ear (0.026), number of kernel/ear (0.087) and number of kernel/row (0.087).Thus positive relation with grain yield, anthesis silking interval, number of kernel row/ear, number of kernel/ear and number of kernel row, etc. and negative association with tassel blast, leaf firing, leaf senescence, ear height, thousand kernel weight, shelling percentage lead to this principal component had variability and selection within this is importance for heat stress condition as shown in Table 3.The present research revealed that these genotype formed in cluster four in heat stress condition were found most tolerant to heat stress. The finding PCA supported the result obtained by cluster analysis and PCA score plot was shown in figure 3.

Table 3: The first four principal components of traits used for cluster analysis and PCA and the eigen analysis of the correlation matrix at NMRP, Rampur,Chitwan (2016).

	Principal components			
Variable	PC1	PC2	PC3	PC4
Eigenvalue	10.935	2.545	1.569	1.293
Proportion	0.578	0.133	0.083	0.068
Cumulative	0.578	0.71	0.792	0.860
Anthesis silking interval	0.257	0.106	-0.104	0.154
Leaf area index	0.120	-0.273	-0.283	-0.489
SPAD Chlorophyll	-0.200	0.145	-0.216	-0.201
Leaf firing	0.216	0.239	0.218	-0.024
Tassel blast	0.229	-0.176	0.074	-0.139
Plant height	0.03	-0.591	-0.147	0.039
Ear height	0.097	-0.538	-0.186	-0.035
Physiological maturity	0.103	0.258	-0.565	-0.009
Leaf senescence	-0.086	-0.149	0.585	-0.397
Ear per plant	0.025	-0.265	0.141	0.708
Cob diameter	-0.295	-0.031	0.046	-0.023
Cob length	-0.275	-0.032	0.001	-0.011
Number of kernel row per ear	-0.297	-0.039	0.019	0.026
Number of kernel row	-0.298	-0.003	-0.000	0.048
Number of kernel per ear	-0.275	-0.052	-0.192	0.087
Silk receptivity	-0.295	-0.02	-0.093	0.030
Shelling percentage	-0.281	-0.016	-0.008	-0.058
Thousand kernel weight	-0.297	-0.015	0.070	-0.009
Grain yield (kg/ha)	-0.286	-0.008	-0.135	0.022

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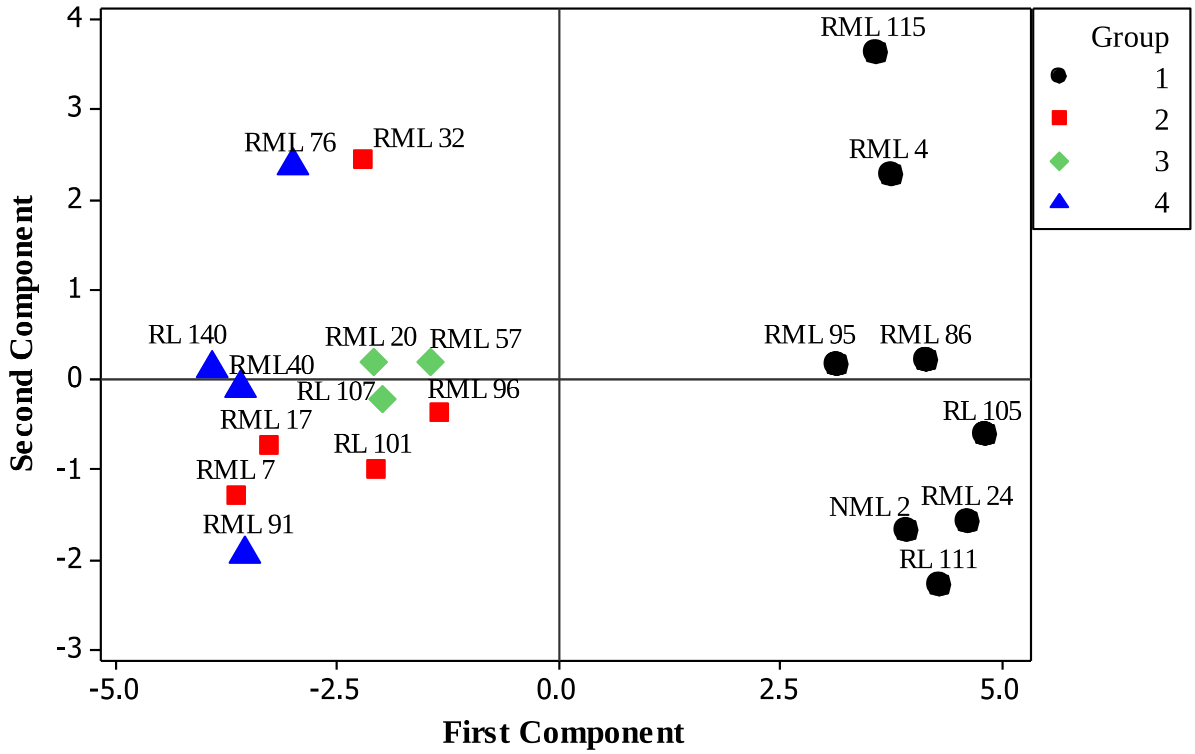

Fig 3: The score plot of first two components of maize inbred lines under heat stress at NMRP Rampur, Chitwan (2016).

DISCUSSION

In present study there is sustainable genetic diversity in grain yield and heat tolerance trait. Khodarahmpour et al. (2011) reported similar finding reduced grain yield up to 70% under heat stress condition in maize inbred lines. Grain yield reduction was associated with poor pollen viability under heat stress condition reported by Rowhani et al. (2011).Pre-anthesis stress in plants absorption of fertilized structure and reduced ear growth rate lead to reduction in kernel number leading to barrenness and ultimate affect crop yield reported by Cicchino et al., (2010b). There were four considerable genetic divergence groups due to genetic factor also subjected to environmental factor. Shrestha (2016) also reported that significant amount of genetic diversity for in maize inbred line for their different morphological traits. Krupakar et al. (2009) also have assessed the range of variability of 16 genotypes for 14 traits in maize. The presence of divergent cluster indicated their superior trait value for heat stressed condition; these inbred lines may be of interest to researcher for abiotic stress breeding. Souza and Sorrels (1991) also reported estimation of genetic diversity and relationships among germplasm accessions facilitates the selection of parents with diverse genetic background which is very essential for breeding program. Thus similar finding about presence of genetic diversity in maize yield and its component were also reported by Singh and Chaudharai (2003).In present study cluster 4 were most heat stress tolerance this finding similar by Ali et al. (2008) who reported that cluster analysis can be useful for finding high yielding genotypes. In this study of principal component

use to reduces of original variables into four principal component and information about each variable which support cluster analysis result. These findings were similar to the results founded by Syafii et al. (2015) and Kamara et al. (2003).In present finding multivariable analysis help to selection of inbred lines for heat stress tolerance breeding: similar to the results reported by Akte ret al., (2009).

CONCLUSION

The genetic diversity was observed in inbred lines differences for grain yield and anthesis silking interval, SPAD reading and leaf senescence, tassel blast and leaf firing percentage, plant and ear height, leaf area index, ear per plant, cob length and diameter, number kernel ear^{-1}, number of kernel rowear^{-1}, number kernel row, silk receptivity, shelling percentage, thousand kernel weight under heat stress condition. UPGMA revealed that inbred lines formed four distinct clusters. The resistant lines and susceptible lines formed different clusters. The member of cluster 4 was found to be tolerance to heat stress where as members of cluster 1 were found most susceptible to heat stress. From this study inbred lines RL-140, RML-76, RML-91 and RML-40 were found most tolerant to heat stress as shown by lower reduction in grain yield and heat tolerance trait tassel blast, leaf firing and shorter anthesis siliking interval. The PCA showed close resemblance with clustering. The presence of high level of diversity among the inbred line for heat stress tolerance grouped into divergent cluster indicated their superior trait value for heat stressed condition; these inbred lines may be of interest to researcher for abiotic stress breeding.

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AUTHOR CONTRIBUTIONS

S.K.G., B. R.O. and J. S. designed the experiment in research field research. M. K. performed experiments, analyzed data and wrote manuscript. S. K. G. and J. S. gave final approval of the manuscript version to be published.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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Performance evaluation of locally developed black light trap for maize insects monitoring in Chitwan, Nepal

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ABSTRACT

Till today, the light traps in Nepal are found using with traditional type, which have not being recognized internationally. These light traps were of low efficiency for trapping insects as compared to black light trap (BLT). The black light tube (F10T8/BL) was used in newly constructed trap at National Maize Research Program (NMRP), Rampur, Chitwan, Nepal. Both traps were installed at the maize experimental field at NMRP during February to October, 2017. Data on insect numbers were recorded once in a week from dusk to down in two different days to minimize the light effects of each others. The total number of insects trapped in BLT was 2804 as compared to 868 in traditional light trap (TLT). Among the insect orders, Coleopterans were mostly trapped in BLT followed by Lepidopteron and Hemipterans. The results showed that the trapping efficiency of BLT was three fold higher than that of TLT. Therefore, black light trap was highly effective monitoring tool and its field applications are expected to be commercialized.

Keywords: Light trap design, Insects attraction, Diversity, Coleoptera, Temperature

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INTRODUCTION

Due to their high ecological diversification and short generation times, insects are useful indicators of environmental change (Thomas, 2005). Light trap is one of the very effective tools for monitoring and management of the insect pests as it mass-traps both the sexes of insect pests and also substantially reduces the carryover pest population. The most widely applied method to survey insects is to use light traps, which exploit their attraction to artificial light (Franzén & Johannesson, 2007). Light traps are also used to determine seasonal patterns of insects' density in the cropped areas. It also provides information related to insect distribution, abundance, flight patterns and helps to decide the timing of the application of management tools (Singh & Bambawale, 2012). There are number of types of light traps designed on the basis of different types of light mechanism. Typically, used lights are standard filament bulbs, mercury vapour bulbs, and fluorescent actinic tubes (Fry & Waring, 2001). The trapping mechanism in the light traps can be designed in various ways which affects trapping performance (Intachat & Woiwod, 1999). Three major factors must be considered in the design of any light trap: the first is an efficient light source, the second is an efficient apparatus for confining the specimens, and the third is an appropriate reception chamber with poison distributing mechanism for killing specimens and retaining them in good condition until they can be recovered for sorting (Hardwick, 1968). At the same time, a range of abiotic factors, such as temperature, rainfall, wind speed, moonlight, and cloud cover, need to be recorded at trap events to correct for their effects on insect flight activity and trap efficiency (Yela & Holyoak, 1997; Beck et al., 2011). Among different types of light trap, the black light trap (BLT) is used for collecting many insects that are active and flying at night and are attracted to UV light. They have consistently caught a higher abundance and greater variety of insects than other traps (Muirhead-Thomson 1991; Neupane, 1982). Their key feature is the low-wavelength light attractant, which lures a diversity of flying insects from the surrounding habitat. Attracting nocturnal insects with ultraviolet light is now in general use and presents the most effective collecting method for nocturnal species of the orders Coleoptera, Othoptera, Lepidoptera, but also for many species of Hymenoptera, Diptera, Neuroptera (Sotthibandhu & Baker, 1979). Different light sources that attract nocturnal insects, emit relatively large amounts of UV radiation (blue fluorescent lights, black lights, and mercury lamps) exert the strongest attraction (Aoki & Kuramitsu 2007; Cowan & Gries 2009). Pennsylvania insect light trap was initially used by the writer as a standard for comparison with other traps and was found outstanding (Frost, 1957). These traps were used for a variety of purposes, ranging from investigations in biodiversity, to pest monitoring, to taxonomic collections and for surveying a wide range of insect taxa (Baker 1985, Beck & Linsenmair 2006). In traditional light trap, a mercury vapour bulb (125-400 W) is used that requires relatively high current to maintain the arc consuming more electric power and thus are limited in its use which has been recovered by using BLT. Since, such BLT has not compared with the conventional trap; this study will shows significant value in monitoring different insects and will provide the reference to the researcher towards using the impacts of such light traps. Thus, the objective of this study was to construct efficient, standardized and cheapest black light trap based on the principle of Pennsylvania light trap, using locally available materials which was evaluated with traditional trap on the basis of insect trapping capacity.

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MATERIALS AND METHODS

Construction features of black light trap

The materials used in Pennsylvania light trap in USA are not available in Nepal thus, locally available low cost materials such as fiber for baffle, wood for tube holder frame, galvanized iron sheet for top cover, funnel and collection chambers and iron angle for support frame. The shape and size of the light trap was modified accordingly keeping basic principle of Pennsylvania light trap. The black light tube (F10T8/BL) used in the model was of 10 watt, emitting 350 nm UV rays. The length of the tube was 33 cm (ϕ 3 cm) which was fitted on the locally available plastic holders in vertical position and electrical connection was made with proper welding of 10 watt electrical chock. The holders were fitted on wooden base frame (Fig 1), which was tightened with the baffles. Four numbers of baffles (41cm long and 12 cm wide and 3.5 mm thick) made of fiber was framed on funnel at one end and top cover at another end (Fig 2). The dimensions of the rain shelter at top, the funnel, the insect collection chamber and iron stand are shown below in table 1. A 60^0 conical funnel having 28.5 cm and 5 cm in diameter at top and neck of the funnel respectively was bolted on the iron angled frame. The insect collection chamber has hanging mechanism on the funnel neck and based on the quick removal iron plate connected to the iron angled frame. The whole trap (Fig 3) has been fixed on the ground such that the lower portion of the light tube installed at a height of 1.5 m. Traditional light trap using 125 W bulb was compared to evaluate the efficacy of two traps.

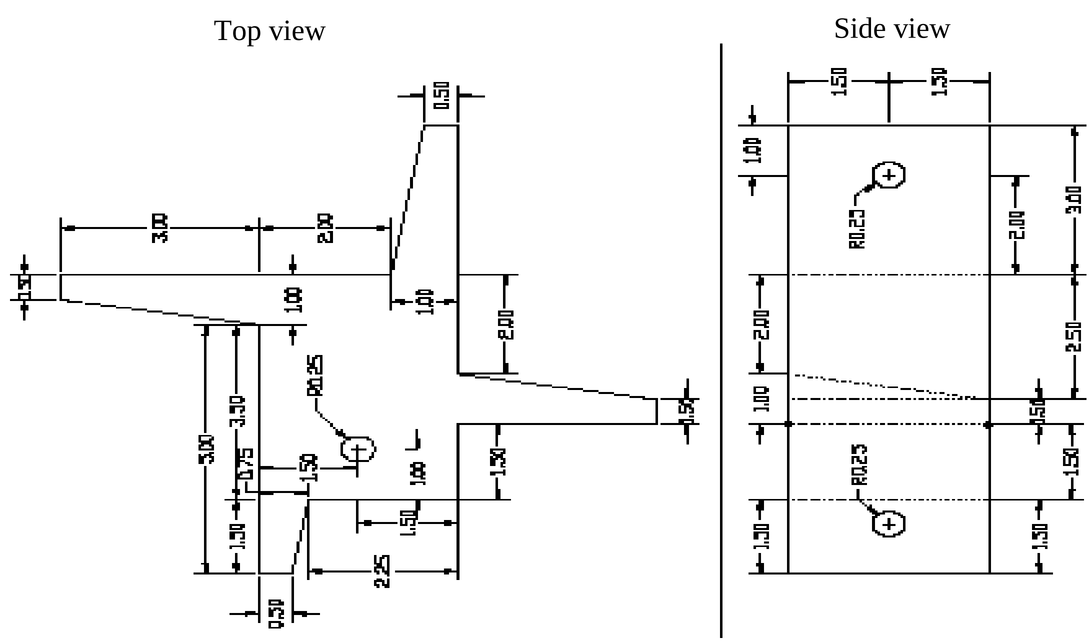

Fig. 1. Wooden base frame for tube holder

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Fig. 2. Baffle fitted with funnel and top cover

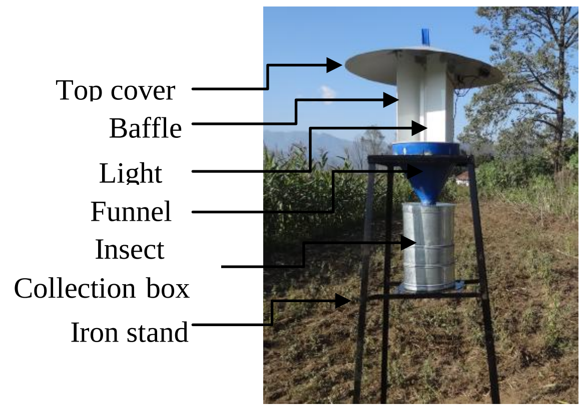

Fig. 3. Installed black light trap (BLT)

Working mechanism of light trap

As mention in the introduction section, the insects attracted due to emitted black light which strike on smooth white baffles surface and hence slide down in the insect collection chambers through funnel. Once the insects fall in the upper collection chamber, the sorting occur when the insects try to fly and find the opening for exit because of different dimensions of sieves at the bottom of each chambers (Fig 4). The sieve dimension of collecting chambers was chosen accordingly to categorize large, medium and small sized insects. This kind of shorting avoids damaging of wings, legs or antennae of insects, which helps identification of specimens. The collected specimens were killed using few drop of poison (ethyl acetate or carbon tetra chloride) in cotton which was kept inside each air tight collection chamber for few minutes.

Data collection

Both traditional and newly constructed black light trap (BLT) were placed in an open maize cropping area at experimental plots of NMRP, Rampur (latitude 27^{o} 40$^{'}$ N, longitude 84^{o} 19$^{'}$ E and altitude 228 m above msl) from February to October, 2017. The measurements were conducted once in a week from dusk to down in the fixed days. The traditional and black light trap were operated in two different days to minimize the light effects of each others. The collected insects were identified upto family level along with their taxonomic hierarchy and biological status to evaluate the performance of both traps.

Fig. 4. Insect collection chamber (a) sieve at bottom of collection chamber (b) insects sorting in different chambers

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Table 1. Construction features of black light trap (BLT)

Part of BLT	Dimension	Specification
Black light tube	Length 33 cm; ϕ3 cm	F10T8/BL; Emits 350 ηm wavelength (λ)
Rain shelter (at top)	ϕ 65 cm	GI sheet (20 gauge)
Baffle	Length 41 cm; width 12 cm and thickness 3.5 mm	Fibers sheet
Conical funnel	Inclination 60^o; ϕ28.5 cm (at top); ϕ5 cm (at neck)	GI sheet (20 gauge)
Iron stand	Vertical height 160 cm; Base plate for funnel 40 cm x 40 cm (at top); foot straggle 65 cm x 65 cm (at bottom)	Iron angle
Insect collection chamber	Top chamber (height 20 cm; ϕ30 cm with led) Middle chamber (height 10 cm; ϕ30 cm) Bottom pan (height 20 cm; ϕ30 cm)	GI sheet (20 gauge)
Base plate for collection chamber	Size 50 cm x 50 cm; Position 68cm from top plate	Iron plate; quick removal mechanism
Sieve mesh	Mesh ϕ 8 mm (for top sieve); mesh ϕ 5 mm for (middle sieve)	GI sheet
Wooden base frame for tube holder	Dimension as shown in fig. 1.	Wood

Weather parameters

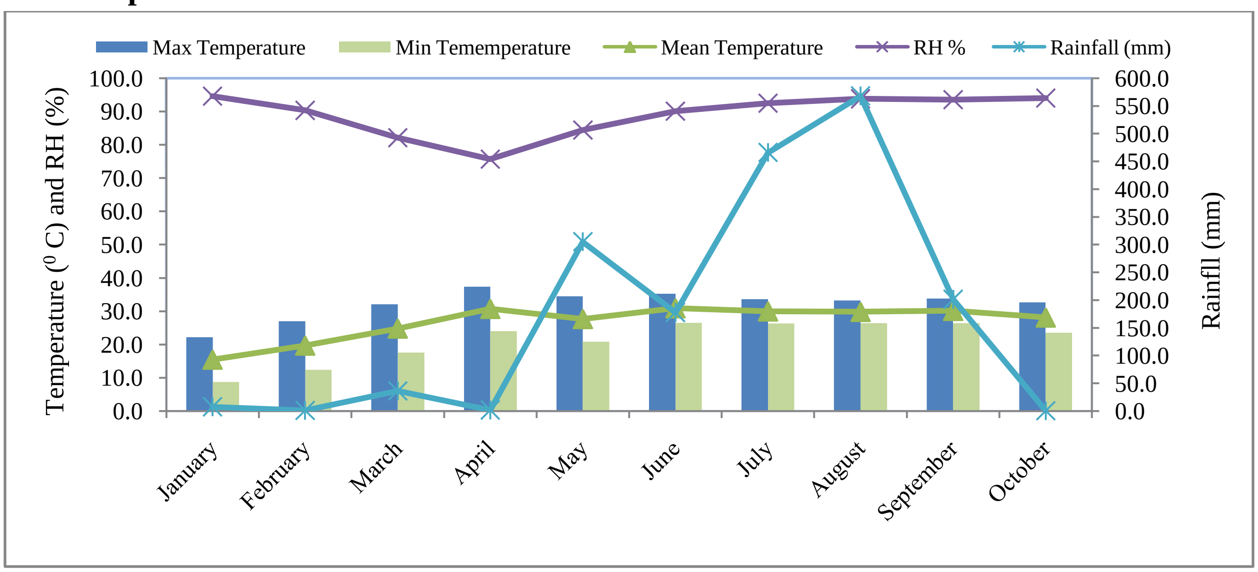

Figure 5: Weather parameters during experiment month of January to October, 2017 at NMRP, Rampur, Chitwan

RESULTS AND DISCUSSION

Insect numbers

Total number of insect catches was found higher in BLT as compared to TLP while monitoring at an interval of 15 days (Fig 6). The highest number (312) was trapped in mid August followed by end of April (295) and end of May (267). This result was similar to the result reported by Muirhead-Thomson (1991) that the BLTs had consistently caught a higher abundance and greater variety of insects during mid April to mid August than other traps. Similar results by (Mellanby, 1939; Holyoak, et al., 1997) showed that the higher insects were trapped from mid-

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May to the end of August. This may be because the higher temperature (Fig 5) increases flight activity and the numbers present in an area of both species and individuals.

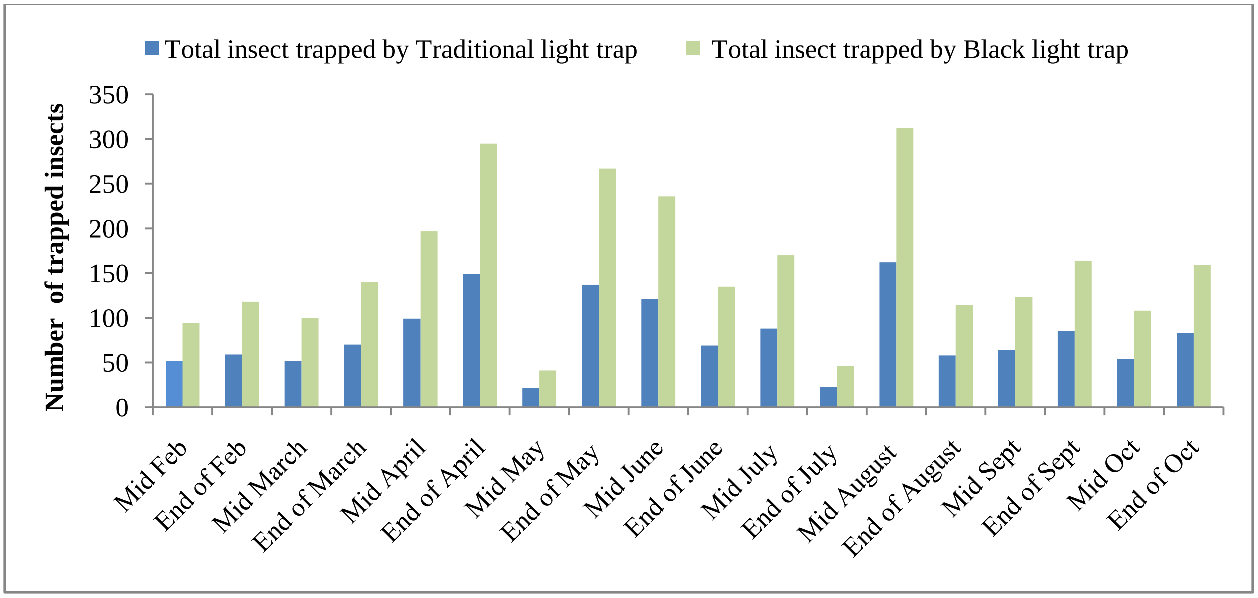

Fig. 6 Proportion of insect species with a peak in abundance in each month at NMRP, Rampur, Chitwan, Nepal, 2017

Insect species

The total number of insect species trapped was found higher in BLT than in TLP (Table 2). Among the trapped insect species in BLT, the highest number of white grub adults (1251) was caught followed by hairy caterpillars (512) and maize stem borers (297) monitored for 8 months from February to October, 2017.

Table 2 Number of insect species trapped at NMRP, Chitwan, during, 2017

Insect category	Insect numbers			
	Traditional light trap		Black light trap	
	Adult (No)	Percent	Adult (No)	Percent
Maize stem borers	67	7.72	297	10.59
White grubs	252	29.03	1251	44.61
Field crickets	82	9.45	253	9.02
Armyworms	24	2.76	73	2.60
Leaf folders	50	5.76	118	4.21
Red ants	82	9.45	245	8.74
Cutworms	38	4.38	55	1.96
Hairy caterpillars	273	31.45	512	18.26
Total	**868**	**100**	**2804**	**100**

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Similar performance was suggested by Kalleshwaraswamy et al. (2016) who collected 131 adults during the trapping period of 30 June -15 October 2013 using light trap. Likewise, Dadmal & Khadakkar (2014) reported that in total 19 species of scarab beetles belonging to 10 genera were the prominent visitors of BLT. The highest number of adult insects trapped in case of black light trap was chaffer beetle (405= 66.83%), where as it was only 22 (3.36%) from an ordinary light trap (Thapa, 2007).

Total order and families

Among various insects collected in the traps, the major contributors were Coleopterans, followed by Lepidopterans, Hemipterans, Orthopterans, Dipterans and Hymenopterans. The result showed that the highest number of catches per family falls under Coleoptera followed by Lepidoptera and Hemiptra respectively (Fig. 7). Dadmal and Khadakkar (2014) observations revealed that Coleopterans followed by Hemipterans and Lepidopterans were the dominating orders caught. Similarly, (Ashfaq et al., 2005) observed the highest number of insects in container placed under the black light (UV light) and the lowest under red light trap.

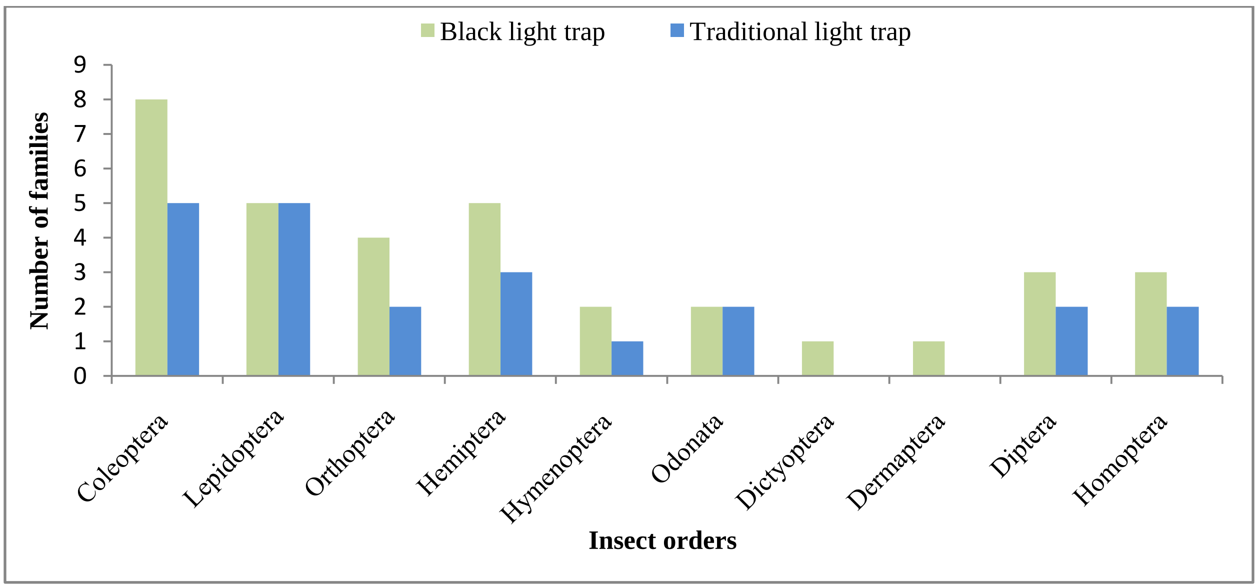

Fig. 7 Insect orders and families trapped through different light traps at NMRP, Chitwan during 2017

Detail cost estimation of black light trap

The detail estimate of all the parts of black light trap is presented in table 3. The cost of all the materials used is as actual rate of local market price in 2016.

Table 3 Estimated cost of black light trap (BLT)

Items	Quantity	Unit	Specification	Cost (NRs.)
Rain shelter, funnel	1	No	GI sheet (20 gauge)	2000.00
Baffles	4	No	Fibers sheet	2150.00
Iron Frame	1	Set	Iron rod	4000.00
Base frame for tube holder	2	No	Wood	500.00
Black light tube	1	No	F10T8/BL (350 mn wavelength)	2000.00
Electric wire, Chock, two pin, holder, screw etc all complete	1	Set	22/7 mm wire, chock-10 watt, plastic holder	500.00
Insect collection chamber with led	1	Set	GI sheet	2000.00
Sieve	2	No	GI sheet	800.00
Fitting charge				500.00
Miscellaneous				550.00
Total cost				**15000.00**

CONCLUSION

Many drawbacks of TLPs have recovered through this study on BLT. The absence of striking and sieving mechanism in TLP has been fulfilled in BLT which helps for catching and instant sorting of trapped insects there by facilitating easy identification of specimens. The insect attracting capacity of BLT (350 ηm wavelength; visible light) was found significantly higher than that of TLP. In same environmental condition and same interval of time, BLT has trapped large number of insect species, families and orders. It is of international standard, durable, portable and having wide range of insects trapping capacity from different habitats. Thus, it can be concluded that monitoring of insect species with BLT can provide thorough knowledge of the insect arthropod composition of an agro-ecosystem, there by identification of pest species, their economic level to start a management strategy. However, further evaluations of BLT in regard to the effect of altitude, crop height, information requirement and subsequent trap designs are required before its commercial branding.

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AUTHOR CONTRIBUTIONS

G.S.B. designed and performed experiments, analyzed data and wrote the paper; S.K.J. designed the light trap; R.B.T., H.K.M., Y.P.G., N.D., P.K.J. and P.T. revised the article for final approval of the version to be published.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Screening of promising maize genotypes against maize weevil (*Sitophilus zeamais* Motschulky) in storage condition

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ABSTRACT

The maize weevil (*Sitophilus zeamais* Motschulsky) is a serious pest of economic importance in stored grains. It causes major damage to stored maize grain thereby reducing its weight, quality and germination. An experiment was conducted in randomized complete block design (RCBD) with 3 replications to screen 32 maize genotypes against maize weevil in no-choice and free-choice conditions at Entomology Division, Khumaltar, Lalitpur (Room temperature: Maximum 24-32°C and Minimum 18-27°C). The findings showed that the maize genotypes had different response to maize weevil damage ranging from susceptible to tolerance. The genotypes Manakamana-3, Lumle White POP Corn and Ganesh-2 showed their tolerance to *S. zeamais* as evidenced by lower number of weevil emerged/attracted, lower amount of grain debris release and lower proportion of bored grains, while the genotype ZM-627 was the most susceptible to weevil damage in both tests. The other remaining genotypes were intermediate types. This information is useful to improve grain protection in storage and varietal improvement/release program.

Keywords: Maize, genotype, storage, *Sitophilus zeamais*, damage, susceptible, tolerance

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INTRODUCTION

Maize is one of the most important food crops in the world with the total production of 1070.5 million t., average yield of 5.96 t/ha, occupying the second position (179.6 million ha) after wheat (220.8 million ha) (Statista, 2016/017). Maize is also the 2nd most important cereal crop in Nepal in terms of area cultivated (891583 ha) and productivity (2.5 t/ha) after rice (1362908 ha and 3.2 t/ha) (MoAD, 2015/016). This crop occupies about 26.9% area of the total cereal cultivated, and contributes to about 25.7% of the total cereal production (AICC, 2016/017). Approximately, 73.5% of maize growing area lies in hilly regions followed by 16% in Terai and 10% in mountain domains (MoAD, 2012/013).

After harvest, maize is stored for household consumption, planting for the next season and for sale. But post harvest losses are high during maize storage in Nepal (Shivakoti & Manandhar, 2000). Ghimire et al. (1996) indicated that the loss in maize grain weight was up to 20% in a typical post harvest storage situation, while KC (1992) reported 15-20% post harvest losses in cereals. According to Sah (1998), weevil caused 51-97% losses in the mid altitude (800-1500 masl) to low altitude (< 800 masl) irrespective of yellow or white maize when stored in a *Kunew* (maize cobs being heaped into a regular shape with no material supports inside the room) for a period of 5 months. In Nepal, maize grain loss due to weevil is high, and affordable alternatives to pesticides are inadequate. Majority of Nepalese farmers are illiterate and resources poor, therefore, they have no proper skills to acquire and handle synthetic pesticides. In such situation, search for effective and resistant/tolerant varieties are worthwhile without any cost to farmers. Insect resistant varieties offer greater advantages in developing countries where farmers can rarely afford to purchase insecticides for crop protection (Mihm, 1997). These varieties provide practical and economic way to minimize field and grain storage losses to improve both quantity and quality of stored grain for planting and human consumption (Simbaras et al., 2013). However, the level of varietal resistance or tolerance to weevil attack is not fully understood in Nepal. Hence, the present study was undertaken to screen different released/pipeline/promising maize genotypes against *Sitophilus zeamais* Motschulsky in storage.

MATERIALS AND METHODS

Maize genotypes selection

Maize genotypes (released/promising/pipelines) were collected from National Maize Research Program (NMRP), Rampur, Chitwan, Regional Agricultural Research Station (RARS), Lumle, and Agriculture Botany Division (ABD), Khumaltar for screening against *S. zeamais* (Table 1).

Weevil inoculum

Weevil culture was maintained in the Laboratory of Entomology Division, Khumaltar, Lalitpur to produce homogenous population (F_2-progeny) for the experiment. The male and female weevils were sexed as per Walker (2008) and Halstead (1963).

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Table 1. Maize genotypes selected for screening against *S. zeamais* in Khumaltar, Lalitpur, 2015

SN	Selected genotypes	Procured from	Remarks
1.	Rampur hybrid-2	NMRP, Rampur	Hybrid maize
2.	RML 32/17	NMRP, Rampur	Hybrid maize
3.	RML 4/17	NMRP, Rampur	Hybrid maize
4.	RML 86/RML 96	NMRP, Rampur	Hybrid maize
5.	Arun-2	NMRP, Rampur	Early maturing maize
6.	Arun-4	NMRP, Rampur	Early maturing maize
7.	Mankamana-3	NMRP, Rampur	Normal season maize
8.	Across 99 42/Across 99 44	NMRP, Rampur	Pipelines
9.	Across 9 331 RE	NMRP, Rampur	Pipelines
10.	Poshilo Makai-1	NMRP, Rampur	Full season
11.	Poshilo Makai-2 (S99TLYQ-B)	NMRP, Rampur	Full season
12.	Rampur Composite	NMRP, Rampur	Full season
13.	ZM-401	NMRP, Rampur	Pipelines
14.	TLBRS07F16	NMRP, Rampur	Pipelines
15.	BGBYPOP	NMRP, Rampur	Pipelines
16.	ZM-627	NMRP, Rampur	Pipelines
17.	07SADVI	NMRP, Rampur	Pipelines
18.	05SADVI	NMRP, Rampur	Pipelines
19.	P501SRCO/P502SRCO	NMRP, Rampur	Pipelines
20.	RML-95/RML-96	NMRP, Rampur	Pipelines
21.	Mankamana-5	RARS, Lumle	Normal season maize
22.	Mankamana-6	RARS, Lumle	Normal season maize
23.	Lumle White POP Corn	RARS, Lumle	Promising line
24.	Lumle Yellow POP Corn	RARS, Lumle	Promising line
25.	Ganesh-2	RARS, Lumle	Normal season maize
26.	Mankamana-1	NMRP, Rampur	Normal season maize
27.	Khumal Yellow	ABD, Khumaltar	Normal season maize
28.	Deuti	ABD, Khumaltar	Normal season maize
29.	KSYM10	NMRP, Rampur	Pipelines
30.	Mankamana-4	ABD, Khumaltar	Normal season maize
31.	Pop Corn	ABD, Khumaltar	Pipelines
32.	Khumal hybrid-2	ABD, Khumaltar	Hybrid maize

NMRP= National Maize Research Program, Rampur, Chitwan; RARS = Regional Agriculture Research Station; and ABD=Agri Botany Division, NARC, Nepal.

All the maize samples were oven dried at 130°C for 1 hr to make them free from insects. The grain moisture content (GMC) of oven dried maize samples was determined by using a WILE - Moisture Meter and then adjusted to 14% moisture for all the genotypes as per methods explained by Cecilia (1990). The experiment was conducted in free-choice and no-choice tests under the Laboratory condition (room temperature: Maximum 24-32°C and Minimum 18-27°C) at Entomology Division, Khumaltar, Lalitpur from April to September, 2015.

Free-choice test

Thirty two maize genotypes of each 50g grain samples were tested against *S. zeamais*. The experiment was set up in randomized complete block design (RCBD) in polythene bottle of 6cm diameter and 7cm height with 3 replications. Four circular holes were made at the bottom at 4 sides with no lid to allow weevils freely enter into the bottle. These bottles were placed in a

circular manner inside a circular wide container (50cm diameter and 18cm height) and 20 days old 800 F_2-progeny of *S. zeamais* (irrespective of sexes) were released in the center. Then the wide container was covered with black muslin cloth. The experiment was set on first week and the first observation was taken for weevil attraction on last week of June, 2015. Subsequent observations were taken on last week of July, 2015 for progeny development and grain damage to each genotype.

No-choice test

For this test also, 50g of maize samples were placed into a polythene bottle of 6cm diameter and 7cm height. Then 20 days old 5 pair of F_2-progeny of *S. zeamais* (male and female) was introduced in each bottle as an inoculum. The mouth of bottles was perforated with black muslin cloth for free air circulation. All the bottles with maize samples along with weevil inoculums were placed inside the wide metal bins (59cm diameter and 33cm height). The experiment was set on RCBD with 3 replications on the second week of July. The observations on number of progeny emerged, the quantity of grain debris released and the number of bored grains were recorded during the last week of August 2015.

Grains bored data were transformed into arcsine. Then data were analyzed using R package for analysis of variance and Duncan Multiple Range Test (DMRT) was used for significant mean separation at 5% level.

RESULTS AND DISCUSSION

The study showed that maize genotypes varied to response to maize weevil attack ranging from susceptible to tolerance, indicating the genotype resistance mechanisms.

Effect of genotypes on number of *S. zeamais* progeny emergence

In no-choice test, there were variations, and the significant differences were observed at <1% level among the 32 genotypes for weevil progeny emergence (Table 2). It ranged from 67.3 to 300.3 mean adult emergence, which was low in Manakamana-3 followed by Lumle White POP Corn, Ganesh-2 and Rampur Composite indicating their tolerance to *S. zeamais*. Similarly, the mean number of weevil was high in RML 32/RML-17 followed by Poshilo Makai-2 (S99TLYQ-B), Poshilo Makai-1, Pop Corn and RML 86/RML 96 showing their susceptibility to *S. zeamais*. The remaining tested genotypes were intermediate types.

In free-choice test also, significant differences were observed at <1% level among the tested genotypes (Table 2). It ranged from 136.7 to 220.7 mean weevil emergence. The mean number of progeny emergence was low in Ganesh-2 followed by RML-95/RML-96, Lumle Yellow POP Corn, Manakamana-1, Lumle White POP Corn, Manakamana-6 and Manakamana-3 indicating their tolerance to *S. zeamais*. Similarly, the mean number of progeny emergence was high in ZM-627, Across 9 331 RE, Arun-4, TLBRS07F16, 05SADVI, RML 32/17 and P501SRCO/ P502SRCO showing their susceptibility to the *S. zeamais*. The rest of the genotypes were intermediate types.

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Table 2. Mean number of *S. zeamais* progeny emergence in selected maize genotypes at Khumaltar, Lalitpur, 2015

SN	Selected genotypes	Mean number of weevil emergence [o]	
		No-choice test	Free-choice test
1.	Rampur hybrid-2	143.7±16.7 g-j	195.7±17.0 a-h
2.	RML 32/17	300.3±30.2 a	210.7±0.3 a-d
3.	RML 4/17	170.3±19.9 b-j	187.3±21.4 a-i
4.	RML 86/RML 96	216.7±24.5 b-e	208.7±29.7 a-f
5.	Arun-2	190.3±10.7 b-i	190.3±30.7 a-i
6.	Arun-4	196.7±35.5 b-h	219.1±22.7 ab
7.	Mankamana-3	67.3±11.9 k	158.7±26.8 e-j
8.	Across 99 42/Across 99 44	191.0±1.0 b-i	163.7±6.4 c-j
9.	Across 9 331 RE	202.3±23.3 b-g	220.3±23.1 ab
10.	Poshilo Makai-1	234.0±20.2 abc	177.0±11.0 a-j
11.	Poshilo Makai-2 (S99TLYQ-B)	242.0±1.7 ab	178.7±18.0 a-j
12.	Rampur Composite	128.0±21.9 h-k	160.3±10.8 d-j
13.	ZM-401	159.0±16.6 d-j	201.3±13.6 a-g
14.	TLBRS07F16	214.0±21.2 b-f	212.7±10.5 abc
15.	BGBYPOP	188.3±20.2 b-i	168.3±12.7 b-j
16.	ZM-627	207.0±35.6 b-g	220.7±12.2 a
17.	07SADVI	166.7±27.9 c-i	209.7±27.2 a-e
18.	05SADVI	149.7±18.9 f-j	214.3±24.8 abc
19.	P501SRCO/P502SRCO	192.7±6.7 b-h	210.0±11.5 a-d
20.	RML-95/RML-96	155±17.1 f-j	141.7±19.1 ij
21.	Mankamana-5	176.7±19.6 b-j	173.7±17.1 a-j
22.	Mankamana-6	153.0±6.1 f-j	156.3±19.9 f-j
23.	Lumle White POP Corn	118.3±37.6 jk	153.3±15.6 g-j
24.	Lumle Yellow POP Corn	189.7±11.1 b-i	146.7±11.4 hij
25.	Ganesh-2	121.0±18.6 ijk	136.7±10.3 j
26.	Mankamana-1	176.7±14.2 b-j	151.0±11.1 g-j
27.	Khumal Yellow	171.7±21.0 b-j	193.7±1 a-h
28.	Deuti	156.7±2.3 e-i	170.0±5.1 a-j
29.	KSYM10	155.3±10.2 f-j	195.7±15.0 a-g
30.	Mankamana-4	163.3±9.0 c-j	163.7±2.6 c-j
31.	Pop Corn	224.7±38.0 bcd	172.3±9.9 a-j
32.	Khumal hybrid-2	156.3±16.3 f-j	185.0±9.50 a-i
	F Value	4.22	2.75
	Probability	$5.65e^{-07}$	0.000352
	CV	20.31%	2.86%
	DMRT	***	***

Values are means of three replications; [0] Means followed by the same letters within each column are not significantly different at 5% level by DMRT.

In both tests, the maize genotypes Manakamana-3**,** Lumle White POP Corn and Ganesh-2 were tolerant to *S. zeamais* attack and the genotype RML 32/17 was susceptible one.

Effect of maize genotypes on grain debris release by *S. zeamais*

In no-choice test, the maize genotypes were statistically significant at 1% level for grain debris release (Table 3). It ranged from 0.2g to 0.7g mean grain debris, which was low in Manakamana-3 followed by Rampur Composite and Ganesh-2 indicating their tolerance to *S. zeamais*. Similarly, the mean amount of grain debris release was high in Poshilo Makai-1 followed by

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Poshilo Makai-2 (S99TLYQ-B, P501SRCO/P502SRCO and ZM-627 showing their susceptibility to *S. zeamais*. The remaining tested genotypes were intermediate types.
Under free-choice test, the maize genotypes were statistically significant at 1% level for grain debris release at 20 days, which ranged from 0.02 to 0.09g (Table 3).

Table 3. Effect of maize genotypes on amount of grain debris release by *S. zeamais* in storage at Khumaltar, Lalitpur, 2015

SN	Selected genotypes	Mean amount of grain debris (g)		
		No-choice test at 50 days	Free-choice at 20 days	Free-choice at 50 days
1.	Rampur hybrid-2	0.37±0.10 b-e	0.04±0.01 g-m	0.48±0.06 c-h
2.	RML 32/17	0.53±0.09 a-d	0.05±0.00 c-l	0.44±0.05 e-h
3.	RML 4/17	0.42±0.11 b-e	0.08±0.01 abc	0.69±0.12 ab
4.	RML 86/RML 96	0.40±0.06 b-e	0.06±0.02 a-h	0.37±0.11 f-k
5.	Arun-2	0.46±0.04 a-d	0.05±0.01 c-k	0.39±0.11 e-j
6.	Arun-4	0.46±0.06 a-d	0.08±0.01 a-d	0.41±0.06 e-j
7.	Mankamana-3	0.21±0.03 e	0.04±0.01 h-m	0.34±0.05 h-k
8.	Across 99 42/Across 99 44	0.53±0.01 a-d	0.07±0.01 a-g	0.50±0.07 c-f
9.	Across 9 331 RE	0.53±0.09 a-d	0.09±0.01 ab	0.59±0.13 bcd
10.	Poshilo Makai-1	0.66±0.01 a	0.04±0.01 f-m	0.45±0.06 d-h
11.	Poshilo Makai-2 (S99TLYQ-B)	0.58±0.05 ab	0.05±0.01 c-l	0.45±0.10 d-h
12.	Rampur Composite	0.30±0.08 de	0.03±0.01 j-m	0.29±0.07 jk
13.	ZM-401	0.42±0.08 b-e	0.04±0.01 g-m	0.60±0.08 bc
14.	TLBRS07F16	0.52±0.08 a-d	0.06±0.01 a-h	0.74±0.08 a
15.	BGBYPOP	0.48±0.05 a-d	0.04±0.01 g-m	0.45±0.03 d-h
16.	ZM-627	0.55±0.08 abc	0.06±0.01 b-i	0.53±0.10 cde
17.	07SADVI	0.35±0.09 b-e	0.07±0.01 a-e	0.43±0.06 e-i
18.	05SADVI	0.38±0.02 b-e	0.09±0.01 a	0.52±0.07 cde
19.	P501SRCO/P502SRCO	0.58±0.06 ab	0.07±0.00 a-f	0.57±0.05 bcd
20.	RML-95/RML-96	0.37±0.06 b-e	0.05±0.00 d-l	0.30±0.02 ijk
21.	Mankamana-5	0.42±0.02 b-e	0.03±0.00 j-m	0.34±0.07 g-k
22.	Mankamana-6	0.41±0.08 b-e	0.03±0.00 j-m	0.29±0.05 jk
23.	Lumle White POP Corn	0.41±0.05 b-e	0.04±0.00 h-m	0.35±0.04 g-k
24.	Lumle Yellow POP Corn	0.47±0.02 a-d	0.03±0.00 klm	0.26±0.04 jk
25.	Ganesh-2	0.32±0.09 cde	0.02±0.00 m	0.24±0.03 k
26.	Mankamana-1	0.50±0.11 a-d	0.02±0.00 lm	0.28±0.06 jk
27.	Khumal Yellow	0.45±0.09 a-e	0.06±0.03 b-j	0.48±0.03 c-g
28.	Deuti	0.51±0.07 a-d	0.03±0.00 klm	0.39±0.03 e-j
29.	KSYM10	0.41±0.08 b-e	0.05±0.00 e-l	0.39±0.05 e-j
30.	Mankamana-4	0.47±0.04 a-d	0.03±0.00 i-m	0.49±0.11 c-g
31.	Pop Corn	0.54±0.17 a-d	0.02±0.00 lm	0.28±0.04 jk
32.	Khumal hybrid-2	0.37±0.04 b-e	0.03±0.01 lm	0.30±0.04 ijk
	F- value	1.609	5.242	8.229
	P-value	0.0547	1.55e^{-}08	1.50e^{-}12
	CV	28.38%	31.37%	17.67%
	DMRT	**	***	***

Values are means of three replications; ^{0} Means followed by the same letters within each column are not significantly different at 5% level by DMRT.

The amount of grain debris release was low in Ganesh-2 followed by Pop Corn, Mankamana-1, Khumal hybrid-2, Lumle Yellow POP Corn, Deuti, Mankamana-5, Mankamana-6, Rampur Composite, Manakamana-4, Lumle White POP Corn and Mankamana-3 showing their tolerance

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to *S. zeamais*. Similarly, the amount of grain debris release was high in 05SADVI followed by Across 9 331 RE, RML 4/17, Arun-4, 07SADVI, P501SRCO/P502SRCO and Across 99 42/Across 99 44 indicating their susceptibility to *S. zeamais*. The remaining genotypes were intermediate types.

In similar test at 50 days, statistically significant differences were observed at 1% level for all tested genotypes (Table 3). It ranged from 0.2g to 0.7g mean grain debris which was low in Ganesh-2, Lumle Yellow POP Corn, Pop Corn, Manakamana-1, ManaKamana-6, Rampur Composite, Khumal Hybrid-2, RML-95/RML-96 and Manakama-3 indicating their tolerance to *S. zeamais*. Similarly, mean grain debris release was high in TLBRS07F16, RML 4/17, ZM-401, Across 9 331 RE, P501SRCO/P502SRCO, ZM-627 and 05SADVI showing their susceptibility to *S. zeamais*. The remaining tested genotypes were intermediate types. In both tests, the genotypes Manakamana-3**,** Lumle White POP Corn**,** Khumal Hybrid-2**,** and Ganesh -2 showed their tolerance to *S. zeamais* and the genotypes RML 32/17, BGBYPOP and ZM-627 showed their susceptibility to *S. zeamais*.

Effects of maize genotypes on grain damage by *S. zeamais*

In no-choice test, statistically significant differences were observed at 1% level among 32 genotypes for proportion of bored grains (Table 4). It ranged from 39.1 to 92.4%. The mean percent of holes was low in Manakamana-3 followed by Lumle White POP Corn and Khumal Hybrid-2 showing their tolerance to *S. zeamais*. Similarly, mean percent of bored grains was high in Poshilo Makai-1 followed by RML 32/17, RML 86/RML 96, BGBYPOP, Poshilo Makai-2 (S99TLYQ-B) and ZM-627 showing their susceptibility to *S. zeamais*. The remaining tested genotypes were intermediate types.

In free-choice test as well, statistically significant difference was observed among the tested genotypes. Mean percent grains bored was low in Pop Corn followed by Lumle Yellow POP Corn, Manakamana-3, Ganesh-2, Khumal Hybrid-2 and Lumle White POP Corn indicating their tolerance to *S. zeamais*. Similarly, mean proportion of holed grains was high in Across 99 42/ Across 99 44, 05SADVI, ZM-401, BGBYPOP, ZM-627, RML 4/17, TLBRS07F16, Across 9 331 RE, RML 32/17 and P501SRCO/P502SRCO indicating their susceptibility to *S. zeamais*. In both test, Manakamana-3, Ganesh-2, Khumal Hybrid-2, Lumle White POP showed their tolerance and the genotypes BGBYPOP, ZM-627 and RML 32/17 showed their susceptibility.

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Table 4. Effect of maize genotypes on grain damage by *S. zeamais* in storage at Khumaltar, Lalitpur, 2015

SN	Selected genotypes	Mean bored grains (%)±SE	
		No-choice test	Free-choice test
1.	Rampur hybrid-2	77.35±9.28 b-f	89.58±2.29 c-h
2.	RML 32/17	91.16±0.13 ab	94.62±0.94 a-e
3.	RML 4/17	75.47±8.95 b-f	94.58±2.29 a-d
4.	RML 86/RML 96	84.54±4.32 a-d	82.83±4.77 g-j
5.	Arun-2	86.48±2.31 a-d	82.29±3.87 f-j
6.	Arun-4	83.31±7.31 a-d	86.85±1.90 e-j
7.	Mankamana-3	39.06±7.02 g	71.01±6.43 kl
8.	Across 99 42/Across 99 44	86.28±0.41 a-d	98.13±1.18 a
9.	Across 9 331 RE	87.37±1.19 a-d	94.68±1.33 a-d
10.	Poshilo Makai-1	92.39±0.58 a	90.13±2.31 b-h
11.	Poshilo Makai-2 (S99TLYQ-B)	90.46±1.18 abc	87.65±2.05 d-i
12.	Rampur Composite	73.12±7.59 def	82.94±1.71 g-k
13.	ZM-401	78.56±7.07 a-f	96.12±0.44 ab
14.	TLBRS07F16	88.01±2.15 a-d	94.79±1.40 a-d
15.	BGBYPOP	90.36±4.06 ab	96.01±0.31 abc
16.	ZM-627	89.75±2.78 abc	94.42±2.43 abc
17.	07SADVI	75.62±6.15 c-f	93.36±2.02 a-f
18.	05SADVI	77.71±9.15 a-f	97.41±1.14 a
19.	P501SRCO/P502SRCO	87.17±2.28 a-d	94.50±0.40 a-e
20.	RML-95/RML-96	72.73±6.46 def	83.13±1.71 g-j
21.	Mankamana-5	87.59±3.59 a-d	83.58±3.80 g-j
22.	Mankamana-6	83.70±3.41 a-e	82.63±6.67 g-j
23.	Lumle White POP Corn	60.65±11.85 fg	78.75±4.20 i-l
24.	Lumle Yellow POP Corn	78.33±1.85 b-f	69.24±0.64 lm
25.	Ganesh-2	75.48±5.55 c-f	76.97±2.57 jkl
26.	Mankamana-1	83.68±2.88 a-e	80.12±7.39 h-k
27.	Khumal Yellow	82.32±1.31 a-e	94.42±0.57 a-e
28.	Deuti	88.74±2.37 a-d	90.63±1.61 b-g
29.	KSYM10	80.05±2.10 a-f	91.07±2.82 b-g
30.	Mankamana-4	85.68±1.57 a-d	90.30±2.98 b-g
31.	Pop Corn	77.84±3.46 b-f	58.63±4.93 m
32.	Khumal hybrid-2	64.29± 11.41 ef	77.27±9.13 i-l
	F-value	3.466	11.52
	P- value	$1.32^{e-0}5$	5.90e^{-}16
	CV	10.37%	5.65%
	DMRT	***	***

Values are means of three replications; SE= Standard error; [0] Means followed by the same letters within each column are not significantly different at 5% level by DMRT.

Effect of maize genotypes on *S. zeamais* preference

In free-choice test, there was a statistically significant difference at 1% level for the mean number of weevils attracted on tested genotypes at 20 days (Table 5). The mean number of weevils attracted to the different genotypes ranged 13.3 to 37.7. The preference was high in P501SRCO/P502SRCO followed by Arun-4, Poshilo Makai-1, Rampur Hybrid-2, Arun-2, RML 86/RML 96 and Pop Corn. Similarly, the preference was low in RML-95/RML-96, Deuti, BGBYPOP, RML 4/17, Manakamana-4, Khumal yellow, Khumal hybrid-2, Across 99 42/Across 99 44, Manakamana-3. The remaining tested genotypes were intermediate types.

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Table 5. Preference of *S. zeamais* at 20 days on selected maize genotypes in Khumaltar, Lalitpur, 2015

SN	Selected genotypes	*S. zeamais* adults attracted (No)±SE
1.	Rampur hybrid-2	33.0±5.13 abc
2.	RML 32/17	20.3±4.91 b-f
3.	RML 4/17	15.7±4.37 ef
4.	RML 86/RML 96	30.0±1.15 abc
5.	Arun-2	30.7±4.06 abc
6.	Arun-4	34.7±7.75 ab
7.	Mankamana-3	18.3±1.20 c-f
8.	Across 99 42/Across 99 44	17.7±2.03 c-f
9.	Across 9 331 RE	25.0±4.93 a-f
10.	Poshilo Makai-1	33.3±3.48 abc
11.	Poshilo Makai-2 (S99TLYQ-B)	28.3±3.18 a-d
12.	Rampur Composite	33.0±5.21 b-f
13.	ZM-401	19.3±3.18 a-f
14.	TLBRS07F16	28.0±5.51 a-e
15.	BGBYPOP	15.7±5.04 f
16.	ZM-627	28.0±2.08 a-d
17.	07SADVI	26.0±3.21 a-e
18.	05SADVI	21.7±2.40 a-f
19.	P501SRCO/P502SRCO	37.7±0.02 a
20.	RML-95/RML-96	13.3±3.28 f
21.	Mankamana-5	20.3±1.20 a-f
22.	Mankamana-6	22.3±2.73 a-f
23.	Lumle White POP Corn	21.3±4.37 a-f
24.	Lumle Yellow POP Corn	18.7±2.03 b-f
25.	Ganesh-2	19.0±2.08 b-f
26.	Mankamana-1	23.3±3.53 a-f
27.	Khumal Yellow	17.7±3.18 c-f
28.	Deuti	13.7±4.18 f
29.	KSYM10	21.7±5.90 a-f
30.	Mankamana-4	15.0±2.65 def
31.	Pop Corn	30.0±3.79 abc
32.	Khumal hybrid-2	17.3±1.76 c-f
	F-value	2.37
	F-test	0.00194
	CV	10.92%
	DMRT	***

Values are means of three replications; SE= Standard error; [0] Means followed by the same letters within each column are not significantly different at 5% level by DMRT.

This study focused to the number of progeny emergence, amount of grain debris release, proportion of bored grains, number of *S. zeamais* attracted as important indicators of a genotype's susceptibility to weevil attack. Abebe et al. (2009) reported that an increasing number of F_1-progeny resulted in an increasing grain damageg and grain weight loss. They found the numbers of F_1-progeny, percent grain damage and grain weight loss positively related with the susceptibility index. Resistance in stored maize to insect attack has been attributed to physical factors, such as grain hardness, pericap surface texture, and nutritional factors, such as amylose, lipid and protein content (Dobie, 1974; Tepping et al., 1988) or non-nutritional factors,

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especially phenolic compounds (Serratos et al., 1987). The role phenolics play in resistance formation in these surface tissues may be both related to structural components and antibiosis factors (Arnason et al., 1993). For weevils, grain hardiness has been reported as the main resistance parameter (Bamaiyi et al., 2007). The difference in the number of weevil emerged showed that there existed variations in susceptibility to maize weevil attack among the genotypes. The genotypes which recorded the higher number of weevil progeny emergence indicated the higher susceptibility to maize weevil attack and this might have been due to lack of resistance mechanisms. The low weevil emergence in genotypes can be attributed to high mortality of parent weevils. These parent weevils might have died before laying eggs thus few progeny emerged. The low weevil emergence in the genotypes may possibly be attributed to absence of essential nutrients and unbalanced proportion of nutrients leading to the death of weevil larvae. The significant variation for number of weevils emerged among the varieties could be due to antibiosis effects in the genotypes leading to retarded development of weevil progeny and sometimes death of weevils before laying eggs. The lower amount of grain debris release could be due to resistance mechanisms in or on the grain which prevented weevil attack. Thus, greater amount of debris released indicates more susceptibility to weevil attack than other experimental genotypes. Simbaras et al. (2013) reported that resistance mechanisms could be in the form of deterrents which could be biochemical or morphological or a combination of both. Biochemical compounds in the form of phenolic amides, such as defeuroyl and dicoumaroyl may be antibiosis factors to the weevil. These phenolic compounds have been detected by fluorescence imaging technique, which clearly shows the phenolic barrier to insects in the outer tissues. It has also been reported that antibiotic effects increased restlessness of insects, which reduced feeding and could explain how grain debris were low among tolerance genotypes. He also noted that variation in maize genotypes was due to antibiosis. Less amount of grain debris release could be attributed to antixenosis mechanisms like a smooth pericarp, which could deter weevils from oviposition and feeding and also prevents mandibles from gripping maize kernels. The great variation observed in the germplasms evaluated forms a genetic resource base for further improvement to raise the levels of resistance to weevils while conserving the preferred traits. This variation on response to *S. zeamais* attack gives an evidence of genetic diversity existence hence a rich genetic resource base for breeding insect resistance. Present findings offer good opportunity to exploit the variability for reducing post harvest insect pest loss, varietal improvement and release through genetic improvement.

CONCLUSIONS

The findings showed that the maize genotypes had different response to *S. zeamais* attack from susceptible to tolerance level. The genotypes Manakamana-3, Lumle White POP Corn and Ganesh-2 showed their tolerance to *S. zeamais* as evidenced by less number of weevil emerged/attracted, low amount of grain debris release and low proportion of bored grains in both free-choice and no-choice tests. The genotypes ZM-627 was the most susceptible one to *S. zeamais*. The remaining tested genotypes were intermediate types. Hence, there is ample opportunity to explore and utilize such genotypes in post harvest insect pest management, maize breeding programs and varietal improvement/release.

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AUTHOR CONTRIBUTIONS

R. B. P. conceived and designed the experiments, collected data, analyzed the data and wrote the paper, and R. B. T. revised the article for final approval of the version to be published.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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